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1. Cox — Jl. A.W.W.A., 31:1489. (1939)
2. Faber — Jl. A.W.W.A., 31:1599. (1939)
3. Weber, Bender, Levine — Jl. A.W.W.A., 32:1904. (1940)
4. Griffin, Chamberlain — A.P.H.A. Paper (Oct. 1944)

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Vol. 37 March 1945 No. 3

Corrosion of Steel and Its Mitigation

By W. R. Schneider

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Presented on Oct. 25, 1944, at the California Section Meeting, Los Angeles, Calif.

IN this paper on corrosion and its mitigation, the discussion will be limited to the corrosion of steel pipes under water or buried in the soil.

Corrosion is caused by electric currents flowing away from the steel surface into the soil or into a solution. These electric currents may be caused by: (1) local action, (2) long line currents or (3) stray electric railway currents.

Electric currents entering steel from a soil or solution do no harm and, if of sufficient intensity, will stop corrosion of iron, even in an acid electrolyte. Figure 1 shows an electric current flowing from the steel surface at *A*, traveling through the soil, water or film of moisture, *F*, to some other portion of the steel surface as *B*. This flow is caused by differences at *A* and *B*, such as:

1. The crystal structure of the steel
2. An inclusion of slag or carbon at *B*
3. Difference in soil or solution
4. Difference in aeration

The metal at *A* is carried away leaving a depression or pit. The loss of metal is proportional to the magnitude of the current flowing from *A* to *B*. This current is increased when the thin surface of moisture film is replaced by a larger mass of water or moist soil, and is still further increased if this water or soil contains soluble salts which will produce an electrolyte of low resistance.

When the distances between *A* and *B* of Fig. 1 are small, and in the order of tenths or hundredths of an inch, the corrosion is known as local action, self-corrosion or galvanic action.

When the distances between *A* and *B* are great, varying from several feet to several miles, the current flowing along the line is known as a "long line current." These long line currents are generally caused by differences in the electrolyte or soil at *A* and *B*.

The most common differences are:

1. Different soils, such as clay, adobe, loam and sand

2. Different moisture content of soil at *A* and *B*

3. Different concentrations of chemical compounds in the soil

4. Different aeration of soils at *A* and *B* produced by compact soils such as clay and adobe, and the loose or permeable soils such as sandy loam

5. Different metals at *A* and *B*, such as steel at *A* and a copper or brass fitting or service pipe at *B*.

These currents leaving at *A* increase the rate of corrosion beyond that normally due to self-corrosion or local action, and the current entering the steel at *B* will decrease the normal self-corrosion at that point.

Localities in which pipes are rapidly corroded are found in cities or localities in which electric railways are in operation. The excessive rate of corrosion is found near the electric station supplying power to the railway system.

The stray railway currents leave the rails at the more distant portions of railway lines and flow on the buried pipes to a point near the power station. At this point the current leaves the pipes to re-enter the rails or station ground and returns to the negative bus. The current leaving the pipe at this location causes the rapid corrosion and failure of the main. Pipeline currents having a definite origin, such as a railway substation, can frequently be rendered harmless by the installation of a drainage bond between the pipes and rails or negative bus.

In order to reduce the detrimental effects of self-corrosion or long line currents, the pipes are usually given a coating or wrapping of some form of electrical insulation, such as asphalt or coal tar. These materials merely reduce the current flow, as they are not, strictly speaking, insulators. They may absorb a certain amount of moisture from the surrounding soil and are then merely poor conductors, permitting pitting to proceed at some point in a positive area.

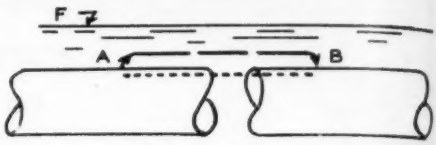

FIGURE 1

A concrete pipe coating, although not a high-resistance electrical insulator, has also proved very effective in combining corrosion, as the cement is alkaline and an inhibitor of the corrosion of steel.

In the interests of economy and operating efficiency it is desirable to locate corrosive areas and apply preventive measures before pipe failures occur. These areas are located by an electrolysis survey. The localities in which pipes, well casings, tanks, etc., are losing current into the surrounding soil or water, and therefore corroding, may be determined in two ways:

1. By measuring the current flowing in the pipe at several points and locating the discharge areas by the loss of current at two points or change of direction.

2. By measuring the earth current flowing to or from a pipe or other structure in contact with the soil, by means of an earth current meter.

When the second method is used, valuable information can be obtained by carrying out the tests of the first method simultaneously, with but little extra expense. The results of the two methods should confirm each other. Failure to do so is an indication that a point at which the pipe is gaining or losing current exists between the two test locations and intermediate tests are desirable.

For a general survey, either or both of these tests are best made during or near the end of the rainy season, when the maximum currents are generally found in the pipes and soil. In many localities, corrosion is seasonal, taking place at a rapid rate during the wet season and decreasing or disappearing during the dry season.

Pipeline Current Measurements

Pipeline currents are measured by the drop-of-potential method, the two contacts on the pipe being made on the pipe at points from a few feet to 500 ft. apart, and the potential measured with a millivoltmeter or potentiometer. The current is then calculated by means of tables giving the current per millivolt-foot, or the known resistances of the various sizes of pipe.

Another method used less frequently is Hering's "divided circuit" method. In this method the current flowing through the main is withdrawn through an ammeter, by means of a battery, until the potential drop between two intermediate points on the main is reduced to zero. The ammeter will then read the value of the current that was flowing in the pipe.

In either method, care is required to avoid including between the potential terminals, pipes of more than one size or weight, service taps or branches, high-resistance couplings, such as leaded joints, flanged fittings, Dresser couplings, etc. Welded pipe connections will not affect the readings.

The potential leads can be fastened to the pipe by welding, brazing, soldering, riveting or clamping with some type of a screw clamp. A riveted connection can be readily made by placing a No. 18 copper wire into a cut made by a hack saw in the side of the pipe, and closing the steel over the wire with a riveting hammer.

All connections should be made in an opening excavated over the pipe for the purpose, in order to maintain both connections at ground temperature and avoid errors due to thermal potential. It is frequently convenient to cover the connection with a few shovelsful of soil or cover the opening to prevent the direct entrance of the sun. The practice of connecting one

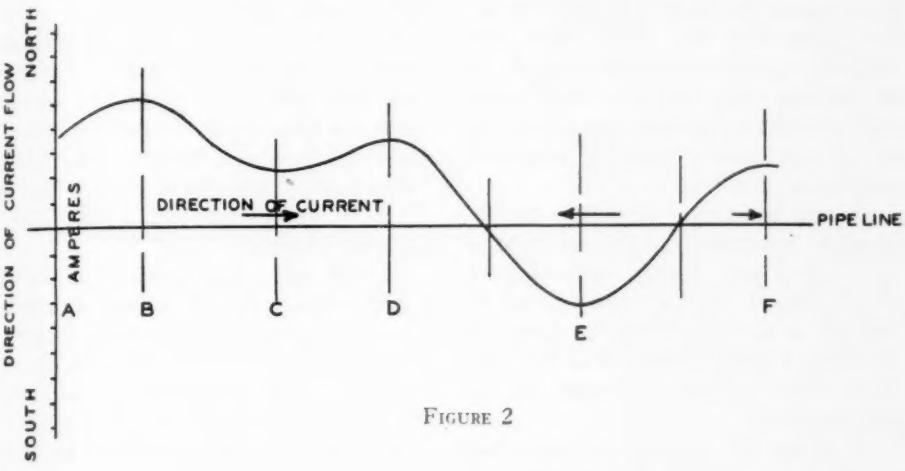

FIGURE 2

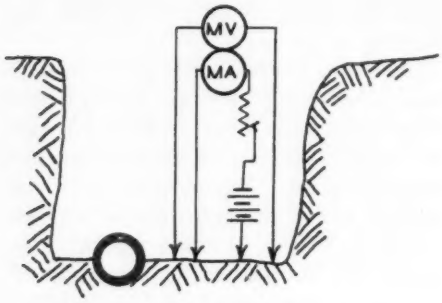

FIGURE 3

lead to the main and the other to a riser pipe or blow-off is not good practice, since the two connections will seldom be at the same temperature. If the readings are found to vary, readings should be taken at one-minute intervals for periods varying from ten minutes to one hour.

If the variations are due to the periodic movement of electric trains, the reading period must cover a complete cycle of train movement and be reduced to a daily average by comparison with a 24-hour record of the particular line or station producing the pipe current.

To locate the positive or corroding portions of a pipe, the magnitude and direction of the currents found during the survey are plotted as shown in Fig. 2. The pipe current is increasing between Station Nos. A and B, C and D, and E and F, indicating that the pipe is receiving current from the soil. The pipe current is decreasing between Station Nos. B and C and D and E, indicating that the pipe is losing current to the soil and, therefore, corroding.

The rate of current loss or corrosion is proportional to the slope or steepness of the curve between two test points. If there are current-carrying branch lines or service connections between two test points, the currents in these branches must be measured and due allowances made in calculating the discharge from the main pipeline. If a large difference in current flow is indicated at two points, it is frequently an indication of an unknown pipe connection or some accidental metallic contact.

In the second method of locating the corrosive or positive areas, the current discharged from the pipe is measured directly by measuring the drop-of-potential between two non-polarizable electrodes placed in the soil on a line at right angles to the pipe.

For this purpose the McCollum earth-current meter is used. The details and method of using this instrument are given in the Bureau of Standards Technologic Papers No. T351, "Practical Applications of the Earth-Current Meter," and No. T355, "Electrolysis Testing."

Briefly, this instrument consists of a high-resistance millivoltmeter, a milliammeter, ground electrodes, a battery, a commutator and the necessary switches. The schematic principle of this instrument is shown in Fig. 3.

Current traveling to or from the pipe will pass radially through the soil under the two electrodes connected to the millivoltmeter, and indicate thereon a potential that is proportional to the soil current and the soil resistance.

By comparing this potential with that shown when a commutated current is sent through the soil from the battery, the magnitude of the current received or discharged by the pipe can be calculated in milliamperes per square foot of pipe surface.

Soil current, when plotted as in Fig. 4, will give a graphical representation of the current received or discharged by the pipe whose pipe currents were shown in Fig. 2.

The portion of the curve above the horizontal line is the positive or anodic area in which corrosion is taking place. The rate at which the pipe is corroding is proportional to the height of the curve at any point.

When the discharge exceeds 1 ma. per sq.ft. of pipe surface, during the wet season, further tests should be made to determine whether a rapid rate of corrosion is being maintained throughout the year. These tests will show whether the yearly loss of weight or pitting is sufficiently severe to warrant rewrapping of the pipe or the application of electrical protection.

For this purpose 3 in. × 6 in. × 1¼-in. corrosion plates or corrosion coupons are installed on all points where excessive pitting has occurred or is anticipated on the pipe (Fig. 5).

These plates are installed in pairs. One, the pipe coupon, being electrically connected to the pipe by means of a cable, shows the effect of both local soil corrosion and long line pipe current discharge. The isolated or "control coupon" is buried at the same depth near the pipe but not connected to it. Its indications are the results of the local action only (see Fig. 5).

The test coupons are allowed to remain in place for one year and from their weight loss and depth of pitting an estimate is made of the theoretical pipe life [Proc. Pacific Coast Gas Assn., 32: 154 (1941)].

Corrosion coupons are maintained on the lines, and, on lines that are electrically protected, they are examined annually to determine the effectiveness of the protection and to give ample warning if this protection has become insufficient due to changes on the pipe system or to soil conditions.

When the electrical protection is properly adjusted the pipe coupon will show no sign of corrosion, either as a weight loss or as pitting.

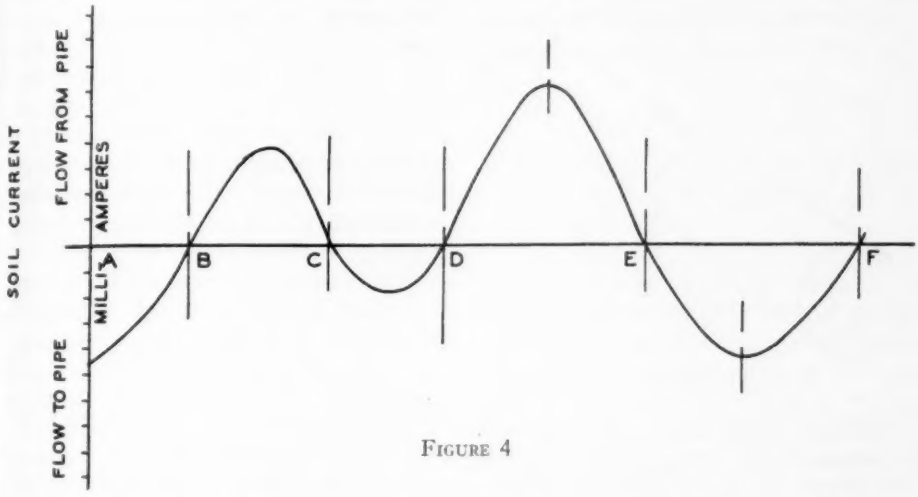

FIGURE 4

Corrosion Prevention

It has been explained that corrosion of steel is due to electric currents leaving the metal and entering a solution or soil. A reduction of these currents will reduce the corrosion. This is

usually attempted by dipping the pipe, wrapping with various materials impregnated with coal tar or asphalt, coating with cement, coating with zinc by the dip or spray process, etc.

The asphalt and coal tar absorb moisture over a period of time and become poor insulators or semi-conductors, and provide only partial protection. Pitting and pipe failures occur under the weakened portions of the wrapping and at breaks and stone bruises occurring during installation or resulting from soil stresses.

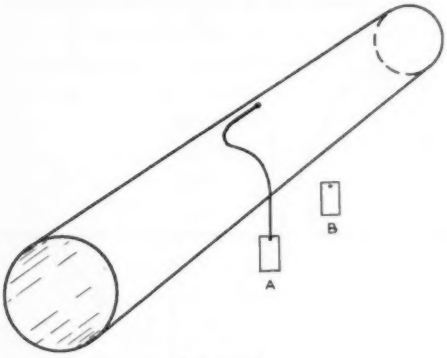

FIGURE 5

"Electric protection," or "cathodic protection," can be used to overcome the defects in the other types of protection, without requiring the excavation of the line, which is a very undesirable and expensive operation, particularly under concrete pavement and city streets.

Cathodic protection protects a pipe by sending an electric current from an outside source to the pipe through the weak spot in the pipe wrapping or to the surface of the bare pipe, neutralizing the electric currents that previously discharged from the surface and caused corrosion.

To protect a pipe or other structure cathodically, the compensating current must be caused to enter the pipe through the soil. This is accomplished by connecting a source of direct current, as shown in Fig. 6, to cause a current to flow from the auxiliary electrode, pilot pipe or anode, to the main being protected. When the adjustments of the protective current are properly made, all corrosion of the pipeline in the area is completely prevented. The corrosion that previously took place on the main line has been transferred to the ground electrode.

Preliminary tests are made to determine the capacity of the direct current supply required to protect a given line. The source of current for this test current is usually a portable storage battery, a portable gasoline engine-driven direct-current generator or a portable welding generator. If a convenient source of power is available, a temporary motor generator set or a rectifier installation can be used.

The positive terminal of the battery or other source of direct current is connected to a temporary low-resistance ground through an ammeter and a rheostat. The negative terminal is connected to the pipe to be protected.

Holding the current at a constant value during the test, soil current readings are taken at several points and at the limits of the positive or corroding portion of the pipeline. In the positive areas the soil current will be found to be reduced or even reversed if the protective current is great enough. It is desirable to repeat this test for several values of battery current.

When the earth current readings are plotted at a given location, against the battery output, a nearly straight line will be obtained. This is used to determine the value of protective current required. The value of protective soil current required, in milliamperes

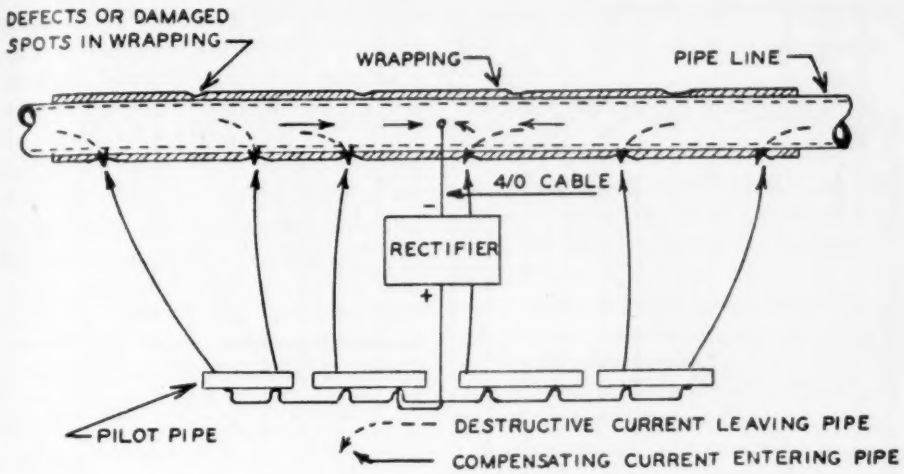

FIGURE 6

per square foot of pipe surface, as indicated by the McCollum earth-current meter, can be determined approximately from the empirical equation:

$$i = \frac{1000}{r}$$

in which

i = current in milliamperes picked up by pipe per square foot of surface exposed to soil,

r = specific resistance of soil in ohms per cubic centimeter, as given by Shepard rod, McCollum meter or laboratory test with a-c. bridge,

1000 = constant, including a safety factor of three, found in laboratory tests on sheet steel. The safety factor compensates for inequalities in the steel, differential aeration, contact with other elements in the soil, such as coke, metallic areas, etc.

The advantage of this equation is that it requires few or no additional tests to obtain the necessary information on which to determine the minimum current required, and it is convenient and sufficiently accurate for practical field use.

The rectifier or other source of direct current is usually given about 25 per cent or 30 per cent greater current capacity than the maximum found during a test made during the wet season. This additional capacity is for the purpose of allowing for variations in ground moisture, deterioration of the pipe coating, extension of the pipe networks, addition of services, etc.

The voltage required at the source of the direct current can be calculated from the known resistances of the various parts of the circuit, including the ground electrode resistance and the back emf. of polarization which may be taken to be about 1.5 v.

To determine the resistance of the ground electrodes, the specific resistance of the soil must be determined. This resistance can be determined from soil samples taken at the ground electrode depth, by means of the a-c. Wheatstone Bridge, Shepard rods or the McCollum earth-current meter.

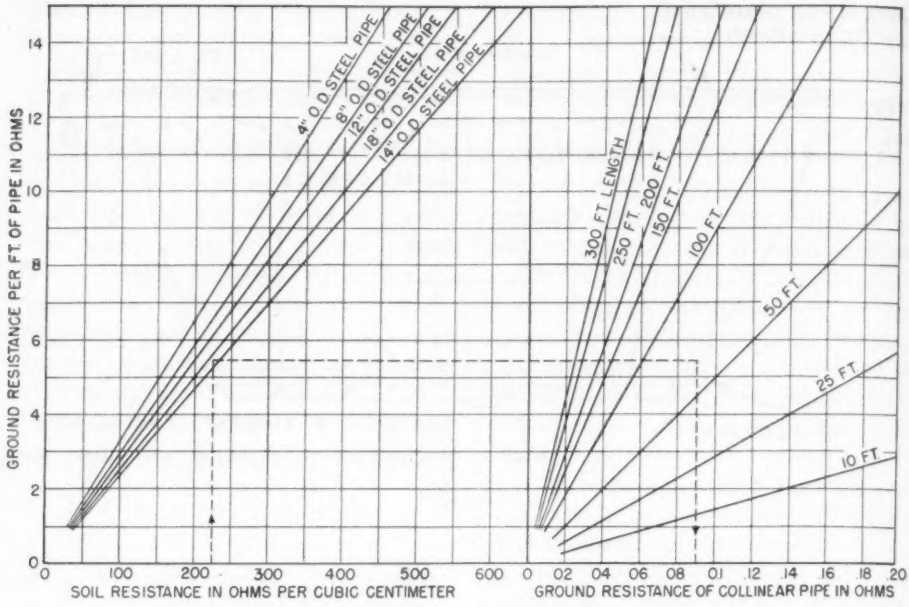

FIG. 7. Resistance of Horizontal Steel Ground Electrodes

The usual ground electrodes consisting of steel pipe are of two general types, the horizontal and the vertical. The amount of pipe and its diameter will vary with the magnitude of the current that is to be discharged, the ground electrode resistance that will be permissible and the length of life that is desired for the electrode.

With a known soil resistance, the amount of pipe required to obtain a desired ground electrode resistance can be found by the aid of charts (Figs. 7 and 8), for horizontal and vertical electrodes respectively. These charts are calculated for soil formations of depths of 50 ft. or more. Shallow soils on a rock formation will give higher values than those indicated by the charts.

A good value of current density on the ground electrodes is 10 sq.ft. of effective surface for each ampere of current to be discharged into the soil. This low density is used to avoid the drying out of the soil by the power loss in the soil in contact with the pipe.

The drop-of-potential between the ground electrode and remote soil is usually limited to 3 v. or less, at full load output of the cathodic protection unit. With this value and the known current which is to be carried, the resistance for which the ground must be designed can be calculated.

The life of the steel ground electrodes is arbitrarily placed at 25 years. At the average rate of wastage in soil (that is, less than 5 lb. per amp. year), the installation of 150 lb. of steel pipe, per ampere capacity of the corrosion eliminator unit, will assure an active life of the ground electrode of 25 to 30 years.

The method of connecting to the ground electrodes and properly insulating the connections, should be carefully studied and supervised. The

connections should be made with a high grade of rubber-covered cable (2/0 to 4/0 size), preferably of the type having a tellurium-bearing outer jacket, and capable of withstanding soil action, fungus or mechanical injury due to rocks, etc. Details of the method of connecting to different types of ground electrodes are shown in Figs. 10–15.

In designing a ground electrode, a number of factors must be taken into consideration when choosing between the horizontal and the vertical types. The advantages and disadvantages of the two types are given below.

Ground Electrodes

Horizontal electrodes consist of rods or pipes laid in a straight trench of sufficient depth to insure a moist soil throughout all or most of the year.

The advantages of a horizontal electrode are:

1. The entire length of the ground electrode is active, being placed in soil of uniform characteristics throughout its length.

2. Large diameter pipes, giving a low ground resistance, can be placed in machine dug trenches, whereas with long vertical electrodes of large diameters this would be difficult.

3. Horizontal electrodes can be placed in comparatively shallow soil formation if necessary, when the hardpan or rock formation is only a short distance below the surface.

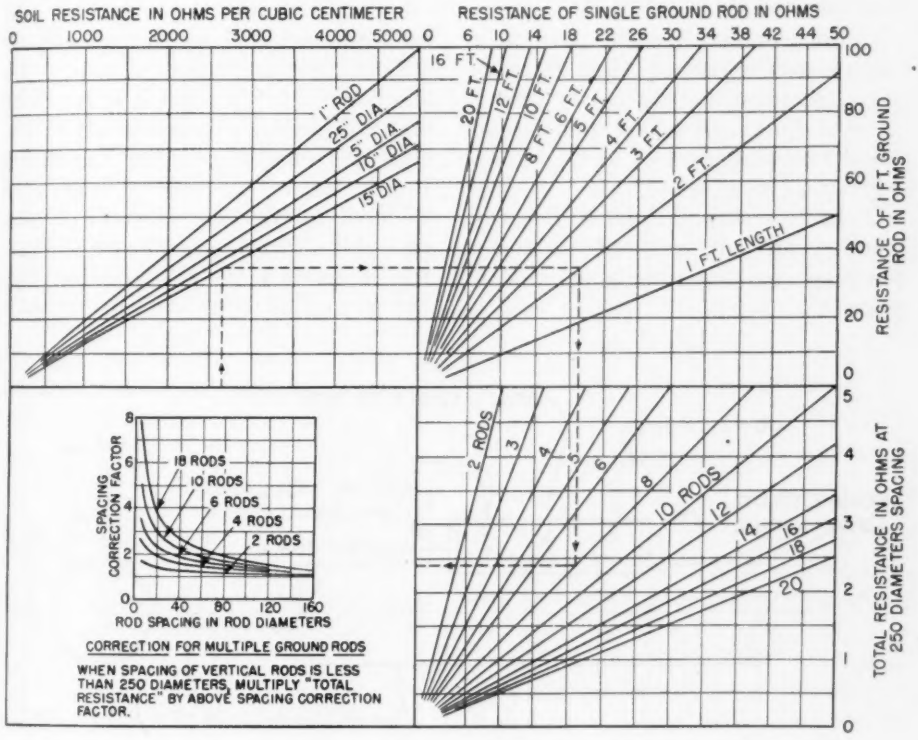

FIG. 8. Resistance of Vertical Ground Electrodes

4. Horizontal pipes, usually in comparatively shallow trenches, can occasionally be examined at a number of points along their entire length to determine their condition and to examine the cable connections, which is not practical with vertical electrodes.

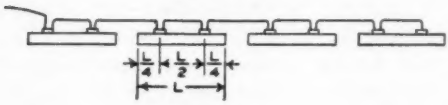

FIGURE 9

5. The entire pipe being placed at least 4 or 5 ft. below the surface of the ground, permits the unobstructed use of the surface for farming or other purposes, and hence a lower cost for the right-of-way.

The disadvantages of the horizontal electrode are:

1. Long or deep trenches cannot be dug in some localities, such as parks or heavily planted areas, in city streets, or near buildings where foundations might be endangered by deep excavations in the nearby soil.

2. In marshes or flooded areas, trenches are not feasible due to the pumping and the cribbing required to prevent a cave-in.

A horizontal ground electrode may be placed in any position with respect to the pipe being protected. It may be parallel to or at right angles to the pipeline, but in no case should it be closer than 50 times the ground electrode pipe diameter.

Steel pipe should be used. Cast iron is not recommended, as this is reduced to graphitic iron having a high resistance by the discharged current and all bonds to cable, made by brazing or soldering, will fall off. The soil should be tamped into uniform contact with the pipe to a depth of 12 in. to insure uniform contact with the metal before the trench is backfilled. The cables should be connected to at least two points on the pipe on each length, as shown in Fig. 8.

In making connections between the cable and the pipe, the braid and rubber insulation is removed over a space of 9 in., and the copper cleaned. An additional 2 in. of braid is removed at each end, but the rubber is left to extend below the asphalt seal, as shown in Fig. 10. The cable is brazed or soldered to the pipe as shown. The pipe and all exposed copper and brazing is primed with a suitable pipe primer and the 4 in. × 12 in. × 2½-in.

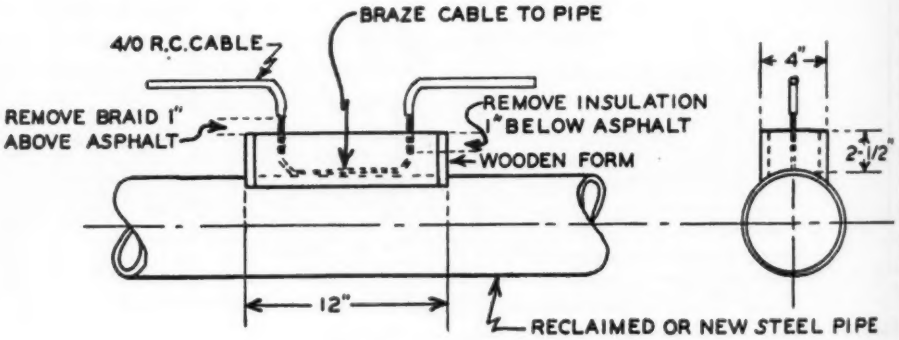

FIGURE 10

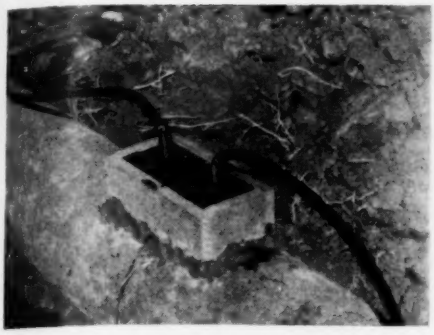

FIG. 11. Completed Connection to Ground Electrode

wooden form is filled with hot asphalt. The forms are allowed to remain when the connection is finished. A completed connection is shown in Fig. 11.

Sufficient slack should be allowed between connections and between pipe lengths to permit uneven settling of the pipe without throwing a strain on the connections. If the connections are made on the bank, sufficient slack should be allowed between lengths to permit lowering of one section at a time into the trench.

"Vertical electrodes" are driven or installed in drilled or jetted vertical openings in the soil. A ground bed of vertical electrodes consists of a number of rods or pipes spaced so as to give the minimum ground resistance that the area of the available property will permit. The total resistance of the ground bed decreases as the spacing of the vertical rods is increased.

The advantages of a bed of vertical ground electrodes are:

1. Vertical ground electrodes are easily installed in soils that are reasonably free of stones, small boulders or other obstructions.

2. Vertical ground rods can be driven in marsh land in which pumps would be required for the digging of a horizontal trench, which would need cribbing to prevent cave-ins.

3. Vertical ground rods can be installed in restricted quarters, between buildings, in parkways, etc.

The disadvantages of vertical ground electrodes are:

1. During a large part of the year, the upper strata of the soil being dry, only the lower portions of the rods are active. This concentration of current on a portion of the rod causes the rapid destruction of the ground electrode.

2. Vertical rods are difficult to install in shallow ground underlaid with hardpan or a rock formation.

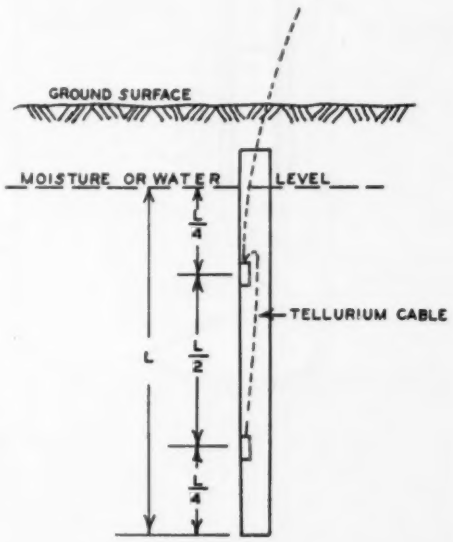

FIGURE 12

3. Due to the depth of long rods or vertical pipes, it is difficult to examine them in place to determine their condition.

4. When installed in cultivated areas, the land must be purchased if the electrodes extend above the ground or are near enough to the surface to

interfere with the surface use of the land.

5. Since vertical electrodes will corrode most rapidly at the moisture or water-table level, a rubber-covered cable must be connected at several points along the vertical electrode, as shown in Fig. 12.

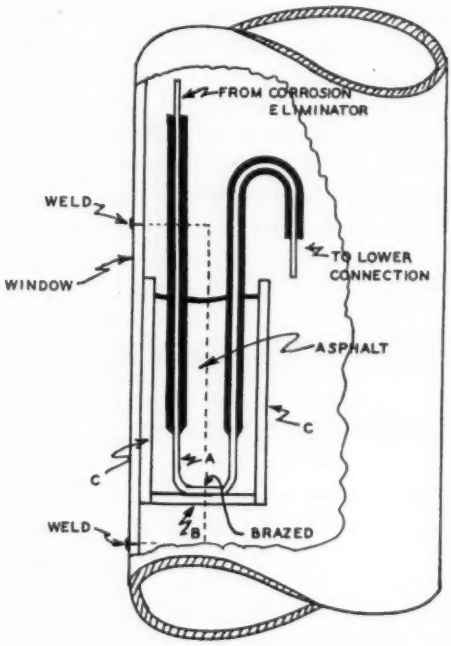

FIGURE 13

Vertical ground electrodes require the same kind of preliminary soil resistance exploration that is required for the horizontal electrodes.

Samples of soil are taken at uniform intervals between the surface and the bottom of the proposed electrode, and the specific resistance of each sample determined in ohms per cubic centimeter. The average specific resistance for use with the chart of Fig. 8 is then found from the following equation for parallel circuits:

$$R_{sp} = \frac{N}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \cdots \frac{1}{R_n}}$$

in which

R_{sp} = average specific resistance of a typical soil of the location tested,

n = number of samples between surface and bottom of electrode.

R_1, R_2, R_3, etc. = specific resistance in ohms per cubic centimeter of samples taken at depth $1\text{–}2\text{–}3 \cdots n$.

The resistance of the ground bed can then be determined when the size, length and spacing of the ground rods have been fixed upon, by reference to the chart of Fig. 8.

The vertical rods or pipes should preferably be spaced at least 250 diameters (ground rod or pipe diameters) apart. If spaced less than this distance the ground bed resistance will be increased and the correct resistance can be found by use of the curves given on the correction factor chart of Fig. 8.

Vertical ground electrodes may be placed in any convenient location with respect to the line to be protected but the nearest rod should not be less than 100 ft. from the line. A shorter distance between the two will cause an excessive pickup of current near the ground bed and reduce the length of line receiving protection.

The active and useful area of a vertical electrode is the portion below the moisture or water level only. The upper portion above the moisture level is merely a conductor carrying the current down to the active portion in the moist soil.

Connections should be made below the moisture level and if the active por-

tion is a pipe and greater than 8 ft. in length, two or more internal asphalt sealed contacts are made, as shown in Fig. 12.

All cable connections must be covered with asphalt to prevent corrosion of the copper through contact with the soil to which it will discharge. Pipes are used for the long vertical electrodes, so the multiple connection can be made internally, as shown in Fig. 12, and thus be protected from an abrasion or other injury during installation.

The details of an internal connection of this type are shown in Figs. 13 and 14. A portion of the rubber-covered cable is stripped for 3 or 4 in. and any braid that may be over the rubber is removed for a distance of 8 in. on each side of the bared copper.

The bare portion of the cable *A* is brazed to a circular disc *B*. The cable is bent in the form as shown and then brazed to the disc which is passed through a 6-in. piece of 3-in. pipe. The disc is then electrically welded into place so that the connection is in a metal cup, which, in turn, is welded to the inner surface of the 6 in. × 12-in. window cut from the 10-ft. vertical pipe electrode.

After filling the cup with asphalt, as shown in Fig. 14, the window is replaced in the pipe opening and welded into place, as shown in Fig. 15. In all cases it is well to coat the outside of the windows with asphalt or other material to prevent the excessive rate of corrosion that would take place at these points.

Direct Current

Direct current for electric or cathodic protection of pipelines is obtained from various sources such as:

1. Zinc plates
2. Batteries
3. Windmill generators
4. Gas engine-driven generators
5. Motor generators
6. Hot cathode rectifier tubes
7. Copper oxide rectifiers
8. Selenium rectifiers

The first four types are used when an electric power supply is not available or is too remote to warrant an

FIG. 14. Vertical Ground Rod Connection Sealed in Asphalt

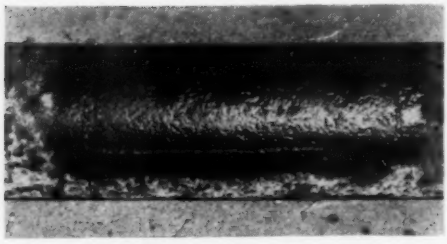

FIG. 15. Connection Completed on Vertical Ground Rod

extension of the service. The operating and maintenance cost of this type of power supply is high, due to the frequent renewal of parts. In the case of zinc, a large number of plates must be renewed periodically. Primary batteries must be reconditioned at frequent intervals. Windmills require occasional oiling and cleaning. Gas engines require attention in the maintenance of oil and water, ignition circuits, commutators, brushes, etc.

Motor generators, although electrically efficient, have the usual maintenance costs characteristic of rotating machinery, the commutators requiring frequent machining when used on this low-voltage service.

The hot cathodic type of rectifier, such as the Tungar and Rectigon tubes, are used when only small amounts of direct current are required, not in excess of 5 amp. The electrical efficiency is low and the tubes must be renewed annually. When a large amount of current is required, the dry type of rectifier of the copper oxide or selenium type is used, power being obtained from any convenient a-c. electric service.

The last type mentioned has the advantage of longer life and little or no maintenance cost. They are so small that a 100-amp. unit can readily be mounted on a power or service pole.

Precautions in Applying Cathodic Protection

Since the cathodic protection of pipes introduces a heavy flow of current into the ground, similar to the stray current from street railways, various precautions are necessary to avoid damage to other parts of pipeline or other underground systems.

1. All insulating or high-resistance connections on the protected line, such as Dresser couplings, flanged fittings, expansion joints, etc., should be bonded over with a rubber-covered copper cable to avoid rapid corrosion on the positive side of the coupling. Copper cables Nos. 1/0 to 4/0 are used ordinarily but in no case is the potential across the fitting allowed to exceed 1 mv.

2. All insulating couplings installed in the lines and services for the purpose of conserving the protective current should be tested on both sides of the connection with an earth current meter. If the positive side is found to be discharging current into the soil, and therefore corroding the pipe, enough current must be shunted around the insulating fitting to reduce this discharge to zero.

3. All branch lines and taps should be insulated if the cathodic protection current is likely to be drawn over a screw-connected pipe network and cause failures at the couplings.

4. If the protective current is likely to be carried from another pipe network to the protected system, as from the water to the gas system through the domestic water heater, the service lines must be insulated and the coupling tested.

5. Parallel cast-iron pipe systems, although having comparatively high-resistance lead or cement joints, may

carry enough current to require drainage to the cathodically protected pipeline.

6. All lead-covered cables within the range of an electric pipe protection installation should be tested for current pick-up or discharge. Both the pick-up and discharge current should be kept near a zero value to avoid sheath failure.

A current discharged from the lead sheath will cause the well-known corrosion due to electrolysis. A current picked up by lead from the soil or duct water will produce alkali, which in turn will dissolve the lead. This secondary reaction is also known as negative electrolysis.

These destructive currents can usually be sufficiently controlled by bonds to the electrically-protected structure, without the need of additional protective equipment.

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Liability for Water-Borne Diseases

By James H. Howard

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Presented on Oct. 26, 1944, at the California Section Meeting, Los Angeles, Calif.

IN recent years the importance which has been attached to the purity of public water supply and the schooling and training of those charged with the responsibility of administering water works has greatly reduced the incidence of water-borne diseases. A traveler may move from coast to coast and drink of the public waters in this country with confidence that the supply is free from harmful organisms. This is true even though many of our cities draw their water supply from admittedly contaminated sources. In such cases it is only the diligence of operators of purification facilities and the efficiency of the methods used that protect the public.

On rare occasions, however, due to personnel or mechanical failure, the germs and other organisms of water-borne diseases are carried to the consumers through the public water mains. In such instances there arises the question of liability for damages suffered by reason of illness or death. It is with the law governing liability for such water-borne diseases that this paper deals.

One of the first questions to be considered is whether or not any difference exists, or any different standards are to be applied, between municipally-owned and operated systems on the one hand and privately-owned public utility systems on the other.

An examination of the authorities indicates that no difference exists. The importance of this phase of the investigation arises out of the fact that, in the performance of many of its public functions, a municipality is an arm of the state government, and is cloaked with governmental immunity from suits based upon the negligence of its employees and agents.

This doctrine has its foundation in the old common-law principle that the Crown could be sued only by its consent. In this country the state is the successor to the Crown, and in performing some of its duties, the city acts as an agent of the state and shares the state's immunity from suit based on negligence of its officers and agents. In most jurisdictions this is true, except as modified by statute, in the matters of fire protection, maintenance of public parks, streets and police departments.

Cities have another capacity, designated, for purposes of convenience, as a private and proprietary capacity, in which they perform functions not governmental in character. When a city steps aside from its governmental duties and engages in a business enterprise, it sheds its cloak of immunity and becomes liable for the acts of its servants and agents in the same manner, and to the same extent, as would a private corporation. This is true of

the operation of gas and electric works and of water works. Particular attention is given to this subject because the supply of water to urban communities is so closely related to the public health, safety, welfare and convenience, that it might well have been classed as a governmental function.

In fact, in discussing an income tax matter (*Brush* vs. *Commissioner*, 81 Law. Ed. 699, 300 U.S. 352) Justice Sutherland of the Supreme Court of the United States had this to say:

> We conclude that the acquisition and distribution of a supply of water for the needs of the modern city involve the exercise of essential governmental functions, and this conclusion is fortified by a consideration of the public uses to which the water is put. Without such a supply, public schools, public sewers so necessary to preserve health, fire departments, street sprinkling and cleaning, public buildings, parks, playgrounds, and public baths, could not exist. And this is equivalent, in a very real sense, to saying that the city itself would then disappear.

The doctrine of governmental immunity from claims predicated upon negligence of agents and employees has, however, always been considered a harsh doctrine. The courts have shown a very natural tendency to limit that immunity to the greatest extent possible without invading the field of judicial legislation.

Despite this close relation to public health and welfare pointed out by Judge Sutherland, the operation of water works by cities has uniformly been held *in tort actions* to be private and proprietary in character and will no doubt continue to be so classified, even though for other purposes, as in tax matters, the operation of water works is classed as governmental.

For the purposes of this discussion, then, what is said with reference to claims based on water-borne diseases attributable to public water supply goes to the question of liability of both public and private corporations.

It should be noted, however, that we are dealing with water serving corporations in their capacity as public utilities. Municipal corporations frequently operate and maintain pools open to the public for recreational purposes in parks and elsewhere. Such pools are sometimes reputed to be channels for the spread of water-borne ailments. Infections of eye, ear, nose and throat are attributed to improperly-maintained swimming pools. It appears probable that, inasmuch as this activity is conducted as a part of the city's power to operate and maintain parks for public recreation, and such operation and maintenance has been classified in the majority of states as governmental in character, municipal corporations would be liable in such jurisdictions only when actions are based upon statute.

As an example, the state of California has authorized suits against municipal corporations even in their governmental capacity, in the event that the injury complained of be attributable to dangerous or defective public works, and when actual or constructive notice of the dangerous or defective condition has been brought to the attention of officers of the municipality having the authority to correct the condition. Except as actions attributable to diseases incurred in swimming pools are predicated on such a statute, it is probable that a municipal corporation in California would not be liable to anyone injured or subjected to disease by negligence of municipal employees in the operation and maintenance of swimming pools.

The basic rule of liability of both public and private corporations for

injury, illness or death attributable to water-borne diseases can be very simply and easily stated. As is frequently the case, however, numerous problems arise out of the application of the simple principle to the facts. In brief, the rule of negligence controls.

The water-serving corporation is not the insurer of the safety of the water supply, that is, it is not absolutely liable in the event that the disease is conveyed through water, nor does the fact that disease is incurred through the water supply raise any presumption of negligence; nor is there any implied warranty on the part of the public utility that the water will at all times be wholesome. To recover in an action against a water-serving corporation, for damage suffered by disease conveyed through the public water supply, it is necessary for the injured party to establish as a matter of fact that the injury was the result of the negligence of employees of the water-serving corporation, in the same manner that it is necessary for the plaintiff in any negligence case to show that the injury complained of is attributable to the negligence of the defendant, his servants or employees.

Examples of Negligence Cases

Possibly the best way to illustrate the point is to consider some of the cases which have arisen, and in which the principle has been applied. The cases to be referred to do not constitute a brief on the subject, and are intended to be illustrative rather than exhaustive. Anyone disposed to follow the subject further is referred to an extensive note in *Negligence and Compensation Cases, Annotated* (Vol. 1, p. 187, Calahan & Co., Chicago (1912)).

The leading case in California, in fact the only case reported in this state in the upper courts, is that of *Ritterbusch* vs. *City of Pittsburg* (205 Cal. 84). Pittsburg is a relatively small community situated on the estuary adjoining the San Francisco harbor. The city had for many years maintained and operated a municipal water supply system for the purpose of furnishing water for domestic use and drinking purposes to the citizens and inhabiants, for which it charged and collected water rates in the ordinary manner. The water was derived from a slough off the San Joaquin River. In the litigation it was a recognized fact that the water in its natural state was not suitable nor safe for human consumption. Unless treated by a purifying process for the purpose of ridding it of typhoid and other bacteria, it was admittedly dangerous to the health of consumers. The city had established a chlorination plant. It was shown, upon trial, that the chlorination process was efficient, when in operation, to remove practically all bacterial contamination and render the water safe for human consumption.

It happened, however, that on a certain night the chorination plant was inoperative during a period of about twelve hours, and that during that time unchlorinated water was, by the agents of the municipality in charge of its water system, permitted to be let into the water mains of the city. There was ample medical and expert evidence to show that the waters, in their thus unpurified condition, would be surcharged with thyphoid and other dangerous germs.

The trial court permitted evidence to be introduced which tended to show that an epidemic of typhoid fever and dysentery broke out in the city within the period of about three weeks following the admission of unchlorinated

water into the water mains, and that, as a direct result of this epidemic, one Carl Rittèrbusch became afflicted with typhoid fever, from which he died.

Evidence also was introduced showing that the period during which the epidemic developed corresponded to the incubation period and the time within which epidemics of typhoid fever and dystentery follow upon the use of infected water.

The upper court took the view that the conclusion was inescapable that the epidemic of typhoid fever and dysentery which broke out in the city of Pittsburg within the period mentioned, after its agents and officials in charge of its water system had permitted unchlorinated water to be served through its water mains, was directly traceable to that cause, and that the death which formed the basis of suit was the direct result of the negligence of the agents and officials of the defendant municipality.

The defendant argued that the epidemic in question might have had its origin in other sources, such as the use of water from wells in various parts of the city. The effect of the evidence was weakened by the fact that these other sources of water supply had existed for a considerable period of time prior to the time of the epidemic in question, and no epidemic had resulted until the particular period following the pollution of the municipal water supply. Among other points, it was urged that the trial court had erred in admitting evidence as to the epidemic. The upper court sustained the trial court in this particular and approved evidence tending to show that the individual whose death was in issue was but one of a large number of persons affected by the epidemic, stating that such evidence would be competent for the purpose of showing that each individual case was traceable to a common source.

The case under discussion was decided in August 1928, and refers to no precedent for the decision. The court assumes, without question, that the ordinary rule of negligence applies and that the city, in its private and proprietary capacity, is liable for the negligence of its officers and agents. The case has not been criticized or overruled in any of the upper courts since the decision was rendered.

It can therefore be said that, so far as the state of California is concerned, the rule is definitely established, and that any action against a water-serving corporation, based upon injury due to water-borne diseases, will be treated in accordance with the principles of negligence actions, and that upon a showing of negligence upon the part of officers or employees, the water-serving corporation will be held for the resultant damages.

An illustration of the application of the principle that no implied warranty exists arises in the case of *Canavan* vs. *City of Mechanicville* (229 N.Y. 473). The city was engaged in the operation of a water plant for the service of domestic water, and through its system typhoid germs were communicated to the plaintiff and his children. The plaintiff's case was based on the theory of implied warranty that the water was pure and fit for human consumption, plaintiff alleging that he had no means of knowing, and did not know, the condition of the water. On the question of municipal liability the court said:

> While the business of maintaining a municipal water system and supplying water to private consumers at fixed compensation is public in its nature and impressed with a public interest, it is not an exercise of gov-

ernmental or police power. A municipal corporation in aggregating and supplying water for the extinguishment of fires discharges a governmental function. In operating a water works system, distributing water for a price to its inhabitants, it acts in its private or proprietary capacity, in which it is governed by the same rules that apply to a private corporation so acting.

It was further held that furnishing of water to private consumers constituted a "sale of goods" within the meaning of certain New York statutes. The court held, however, that since the plaintiff's allegations as to the alleged warranty sprung solely from the furnishing and taking of water, notwithstanding the fact that the supply of such water constituted a sale of goods, the city did not impliedly warrant that the water furnished was wholesome at all times and under all conditions. The court said:

It is a matter of common knowledge that human skill or judgment cannot unceasingly and under all conditions and circumstances see to it that no unwholesome water is furnished. It is also a matter of common knowledge that a company or municipality does not know that any particular use is to be made or any particular portion taken. Of the water taken the part not used for drinking or human consumption is much the greater. The conditions which uphold the liability of the market man or grocer do not exist.

The case being predicated upon implied warranty rather than upon a charge of negligence, and the court having held that no implied warranty exists, no recovery was had.

In another New York case, *Stubbs* vs. *City of Rochester* (226 New York 516), the principles of negligence were applied. The facts were that the city had two systems of water supply, one brought from Hemlock Lake to reservoirs and thence distributed by gravity to consumers; the second, or Holly system, was for fire purposes in the business district, the water being pumped from the Genesee River near the city and emptied into a separate set of distributing pipes. The Erie Canal ran through the city and bridges over the canal were operated by hydraulic pressure. The supply of water for the hydraulic lifting equipment was derived from both sources. If the gates in both pipes were open at one time, both systems discharged water into the lifting equipment. The plaintiff was a machinist, employed in a factory about one block from a bridge so operated, and the factory was supplied, or purported to be supplied, with Hemlock Lake water for drinking purposes. The plaintiff contracted typhoid fever by drinking from the factory water supply.

The evidence clearly established the fact that the water in the locality of the bridge was contaminated. The negligence charged was that the city carelessly permitted polluted water from the Genesee River to reach the Hemlock water through the Holly system. The defendant had judgment in the lower court, but the case was reversed on appeal, the upper court holding that in order to recover, the plaintiff was not obligated to eliminate all possible causes of his disease other than the defendant's negligence.

Evidence that the plaintiff drank water near the alleged point of contamination and that some 60 cases developed in the same locality, that his physician testified the pollution in question was the cause of the illness, and that the plaintiff's habits were such as tended to exclude any other possible source, was held to be sufficient to justify the submission of the case to the jury, and that a verdict rendered

thereon would not rest on conjecture, but upon reasonable possibility.

In the case just discussed the court clearly stands on the principle of liability for negligence.

Another interesting New York case is that of *Wiesner* vs. *City of Albany* (224 App. Div. 239, affirmed 250 New York 551). Again, the action involved typhoid fever alleged to have been contracted from using water furnished by the defendant city. The water supply involved was derived from the Hudson River, a highly polluted source. The city filtered the water and introduced chlorine for purification purposes. After treatment, the water was conducted through a conduit, approximately 8,000 ft. long, to a pumping station for distribution. The conduit was old, rusty and broken, having been in service for more than twenty years. Apparently the conduit was not under pressure, and holes in the pipe permitted entry of ground waters, which had the effect of polluting the water in the pipe. The city was held liable for negligence of its officers in not exercising reasonable care to provide wholesome water, after having knowledge of the defective conditions.

The case of *Roscoe* vs. *City of Everett* arose in the state of Washington (136 Wash. 295). There was a bypass connecting the city water mains with the water pipe of a mill company which drew its supply from a polluted source. For this reason it was dangerous to leave any gate valve open in the bypass. The officers of the defendant city had never inspected the bypass valve after the installation of a new water main. The valve in question was open at the time that it was alleged that the plaintiff's intestate had taken the polluted water. It was held that the evidence was sufficient to sustain a charge of negligence and a judgment against the city.

It is to be noted that in this case the negligence was negative in character. In the case last discussed (*Wiesner* vs. *City of Albany*) the court mentions the fact that the city had knowledge of the dangerous condition of the conduit which permitted pollution. In the case under discussion apparently the officers of the city had no knowledge of the dangerous condition, the holding being that in the exercise of ordinary care they should have had such knowledge, and failure to make the necessary inspection and to correct the condition constituted negligence.

Another Washington case, *Aronson* vs. *City of Everett* (136 Wash. 312), is more interesting from the standpoint of pleadings and evidence, but the principle of negligence was the basis of the case. The pollution causing the injury sued on, as in the Roscoe case, came through the mains of a mill plant located on the river. The plant was connected with the city water system, even though it had its own pumping system. The water taken by the mill company from the river was not fit for human consumption. There was a series of check valves, intended to prevent such water from getting into the city mains, but a bypass had been installed, with a gate valve which was designed to be kept closed. The court ruled upon the principle that a municipal corporation engaged in furnishing water to its inhabitants at a profit may be held liable in damages resulting from negligence in the same manner as a private corporation engaged in a like business. It was held that the plaintiff's action was based on negligence and not upon the theory of implied warranty.

There are numerous other cases involving similar questions, but enough has been said to illustrate the principle which is, in general, operative in all states of the union where there has been occasion to consider the problem.

It may be mentioned that there is no obligation on the part of a water-serving corporation to serve chemically pure water or water adapted to all commercial enterprises. It is sufficient that care be exercised to the end that the water may be wholesome and fit for human consumption.

In general, the courts appear to recognize the fact that municipalities and water-serving public utility corporations are confronted with many practical problems in accumulating, transporting and serving water. The courts do not expect the impossible, but do expect those in charge of the administration of public water supplies to exercise care and reasonable diligence for the protection of the public, and have no hesitancy in holding the water-serving corporation liable in the event that adequate proof be made of the absence of such care.

Classification and Control of Maintenance

By F. R. Berry

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Presented on Jan. 17, 1945, at the New York Section Meeting, New York, N.Y.

DURING this period of manpower shortage and the need for conserving critical materials, the companies with which the author is associated have found it necessary to institute certain controls on maintenance, in an effort to see that maintenance which is necessary for the operation of their water works properties is not slighted, and that other maintenance is deferred. To accomplish this it was necessary to classify maintenance. In the past, maintenance had been generally classified under three headings, namely, necessary, advisable and desirable. It was found that these adjectives were not definite enough and were subject to many interpretations. A broader and more definite classification was needed. After a good deal of discussion and thought, maintenance was divided into six classifications as follows:

1. *Emergency Maintenance*—That necessary to restore to a condition of usefulness an item of property essential to operation.

2. *Essential Maintenance*—That necessary to insure the continuance of operation of an item of property essential to operation.

3. *Required Maintenance*—That necessary to comply with public authority.

4. *Necessary Maintenance*—Essential maintenance which can be scheduled.

5. *Deferable Maintenance*—That done partly for the sake of appearance and which may be deferred for substantial periods.

6. *Marginal Maintenance*—That which is of doubtful value.

The first classification, "emergency maintenance," includes all breakdowns which affect either continuity or reliability of service as, for example, broken mains, fire hydrants, services, etc. It also includes breakdowns in pumping equipment. In the latter category, while service may not be directly affected, there is a potential danger as the capacity of the reserve equipment is reduced. It is evident that necessary repairs in this emergency category must be made as promptly as possible. In many cases, overtime work and bonus prices for material are necessary.

The second classification, "essential maintenance," should include most of the maintenance which is done in the normal operation of the water works plant if the "emergency maintenance" is excluded. In this category would be included the normal overhauling of pumping equipment, painting when needed to protect painted surfaces from deterioration, periodic inspection, and maintenance of fire hydrants, valves, etc. Maintenance work in this category should, if possible, be scheduled during the year in order to make the

best use of the available manpower and materials.

"Required maintenance," in many instances, will have to be done in order to comply with the requirements of public authority. However, much of this work can be anticipated and scheduled for periods when it will cause the least disruption in normal routine operations. For instance, in this classification would be included the lowering of pipelines in advance of street improvements. In general, a water works manager can know in advance the city's street improvement program, and can make plans for pipe lowering, service line replacements or other necessary work well in advance of the time when the actual street improvement work is started.

The fourth item, "necessary maintenance," is just one step below maintenance in the second group, and includes many items which are done in advance of actual needs; an example is the painting of structures where the existing painting has not deteriorated to an extent which would result in injury to the protected surfaces. There should be a certain amount of maintenance planned for this fourth category as this will enable a better utilization of all the available manpower, and even though the work is done in advance of actual need, it will be more economical than to have available facilities which are not fully utilized.

It is much more satisfactory in the operation of a water works plant to employ an operating personnel of moderate size and to provide reasonably uniform and continuous employment than to employ inefficient, untrained, casual labor, unless such labor is hired to dig trenches and similar work where previous training is not necessary. A small, well-trained organization, with assurance of continuity of employment, will be found much more efficient and economical than temporary employees who usually have little interest in their work. Maintenance work in this fourth category should be done with the object of accomplishing a high degree of utilization of manpower, without the necessity of frequent layoffs and inefficient work by unskilled personnel.

The next two categories, namely, "deferable maintenance" and "marginal maintenance," should, during this period of manpower and material shortages, be eliminated. There is too much need for manpower and material to carry on work in these categories. After the wars are won, it may be that there will be a surplus of manpower, in which case it probably will be desirable to do some maintenance work in the fifth or even the sixth group.

The author's experience has been in connection with the operation of privately-owned water works plants. The conditions in a municipally-owned plant, however, are similar enough to make the problems substantially the same. It has been found very helpful to have available a standardized maintenance classification, and an attempt has been made to make it so comprehensive that there can be little room for differences of opinion regarding the classification into which each maintenance job will fall. Once a job is classified, it is a simple matter to determine how it should be handled.

Uprating McMillan Slow Sand Plant

By J. C. Smith

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Presented on Nov. 10, 1944, at the Four States Section Meeting, Philadelphia, Pa.

THE McMillan slow sand filter plant is an old friend to a great many water works engineers, operators and manufacturers, and this old friend is now undergoing a rejuvenation.

A program of plant improvements, the first since the plant was placed in service in 1906, was initiated at about the time the latest national war emergency began. Washington Aqueduct, the supply division of the national capital's water system of which McMillan is a part, was denied needed materials and equipment for plant expansion during the first two years of the war when the demands of the armed forces had first priority. The service life of old machinery and undersized and outmoded structures and facilities had to be stretched to meet ever increasing demands. Everywhere ingenious "Goldberg" devices for water treatment, control and pumping facilities were developed and substituted for the then unobtainable manufactured products.

McMillan plant held a few strategic advantages in that the appurtenant features, such as filter underdrains, collection mains and sedimentation basins, were capable of handling increased production, provided that an ample quantity of water of a suitable quality could be supplied to the filters. Just before the emergency period, construction of a new 20-mil.gal. reservoir was initiated. It was placed in service early in 1943 and not only smoothed out filtering fluctuations but also increased storage capacity and assisted greatly in meeting peak demands. While the plant operated through the summer of 1942 at about its designed sustained capacity of 75 mgd., the operations during that season plainly indicated that greater demands would be placed on McMillan and that uprating would have to begin upstream from the slow sand plant.

The Potomac River has proven an unfailing source for Washington's water supply since the aqueduct system was placed in service in 1863, but it has not been corollary that water be delivered in sufficient amounts to McMillan. A profile diagram showing flow line from the raw water conduit intakes at Great Falls, Md., to the McMillan filtered-water storage reservoirs is shown in Fig. 1.

Uprating of the McMillan plant began with the installation of a homemade propeller-type pump at the outlet end of Georgetown Reservoir. Operation of this pump increased the quantity of water flowing through the 4-mi. aqueduct tunnel to the McMillan open reservoir and raised the surface elevation of the latter to maintain a large storage capacity. Delivery of water under these operating conditions approximated 100 mgd., which was an in-

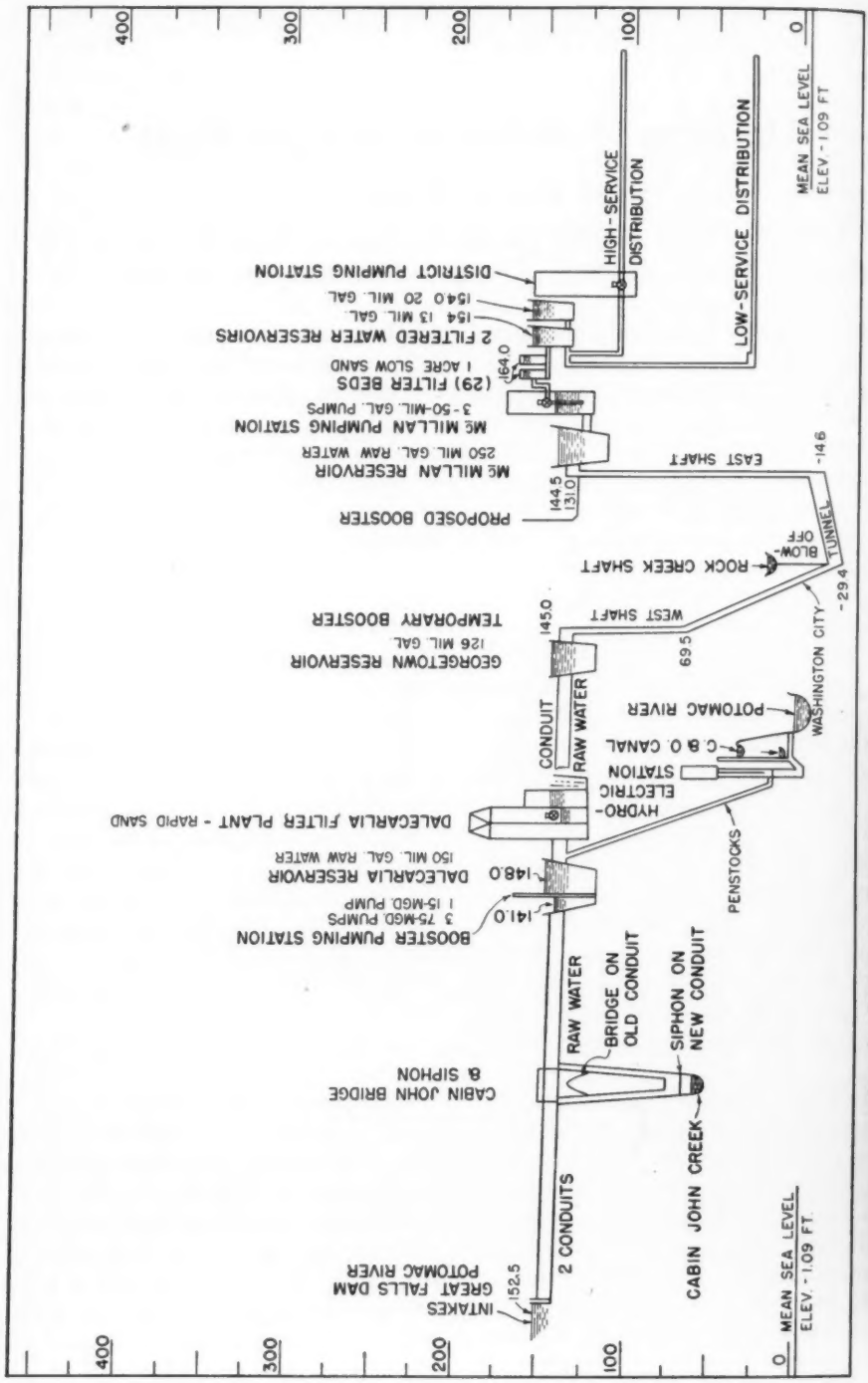

FIG. 1. Flow Line From Conduit Intakes at Great Falls to McMillan Reservoirs

crease of 33 per cent above the original designed capacity of the tunnel.

Figure 2 shows the propeller pump in operation. As the water surface within the open discharge well is very turbulent, the pump is locally called an "eggbeater." The inclination of the shaft is 51 deg. from the horizontal while in operation. A steel plate attached to the unit and built to shroud the impeller forms a stop wall between the pump well and reservoir. The unit was developed by the Operational Superintendent of the Washington Aqueduct and was originally fabricated, except for the sheaves, V-belts and motor, with materials salvaged from discarded boat and dredge machinery. The motor is a variable-speed squirrel-cage type and the unit operating efficiency is about 60 per cent. In the future, the pump will be retained as a standby when the new booster unit is installed at the McMillan Reservoir tunnel outlet.

Figure 3 shows the layout plan of the present McMillan slow sand filtration plant with its 38-acre, open, raw-water storage reservoir, pumping station, 29 one-acre covered slow sand filters and their accessories, together with the two covered filtered-water reservoirs. One of these has previously been mentioned and the other, having a 15-mil.gal. capacity, is part of the original plant construction.

Improvements in Plant Facilities

Uprating within the plant has so far been accomplished by improving operating conditions on the collecting system and by procuring new equipment for plant chemical application and self-propelled sand washers.

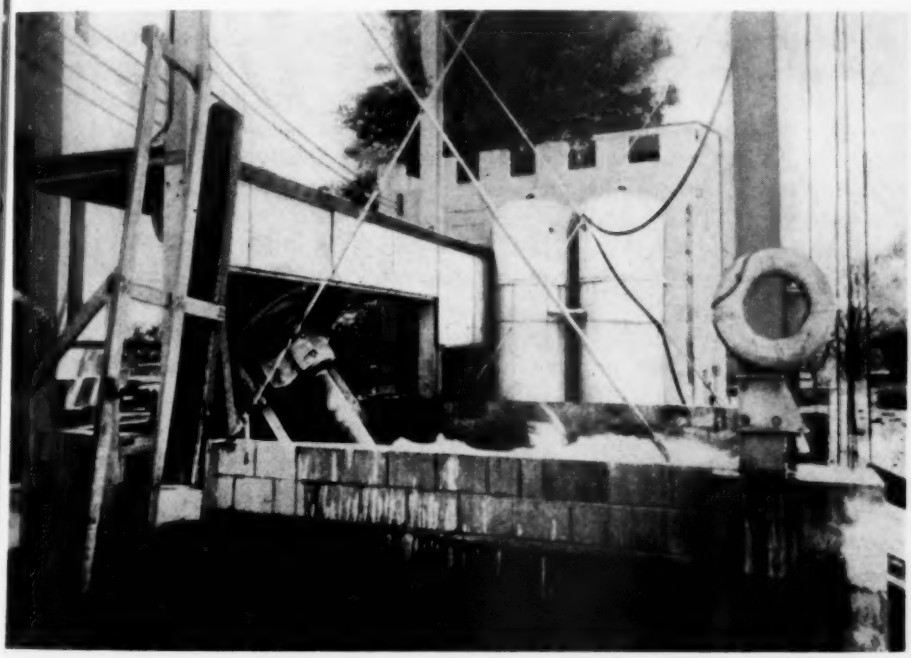

Fig. 2. Propeller Pump in Operation

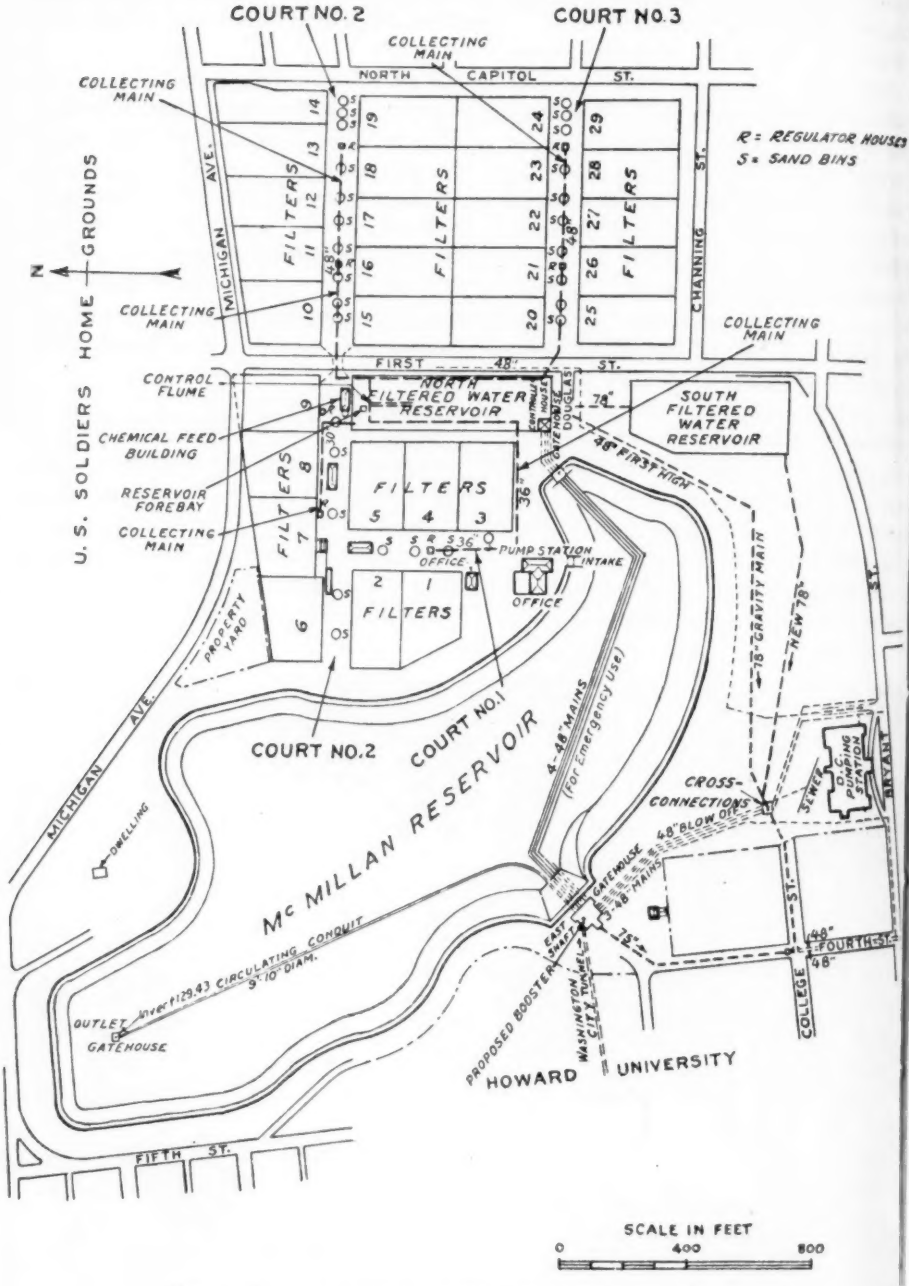

FIG. 3. Layout of McMillan Slow Sand Filtration Plant

To facilitate filter operations and output control, a new flume with control appurtenances was constructed. All of the filter collecting mains discharge into a forebay at the north end of the originally constructed filtered-water reservoir for the purpose of admixing chemicals for sterilization and corrective treatment. The forebay has been revamped to include a reinforced concrete pipe discharge flume so that the rates of filtration from all 29 filters can be regulated to meet the demand conditions by push-button control of a motor-operated butterfly valve. A metering device is also installed within the flume to gage the regulation of applied chemicals. The new forebay and flume alterations have increased the hydraulic efficiencies of the filtered water collecting mains, thereby increasing the rates of flow to the reservoir.

Coincident with the uprating of the filters, sterilization of the increased production required that two new chlorinators of 1,500-lb. capacity be installed. Evaporators are scheduled for near-future delivery to increase the flow of chlorine from the presently used 1-ton chlorine cylinders.

Provision has been made to apply lime to the filtered water at a point located within the reservoir approximately 600 ft. from the point of chlorine application. This was accomplished by suspending an 8-in. steel pipeline from the reservoir roof and installing a cleaning device operated by air motors which drags a steel pipe scouring shell or "Go Devil" from one end to the other within the lime line. A new lime feeder of 5-ton per day capacity to replace the present 2-ton machine is scheduled for a near-future delivery so that corrective treatment may be applied as required under uprated plant operations.

During 40 years of operation the filter sand in the McMillan filters had not been cleaned to its full 36-in. depth. Sand cleaning according to original practice was accomplished by hand shoveling of the sand into hydraulic ejectors for removal from the beds and subsequent washing and storing in concrete bins. A cleaning constituted the removal of a 2-in. layer and, after six such operations, the washed sand was replaced by hydraulic methods over the 24-in. depth remaining in the filter. The practice of resanding, together with the normal filtration of water containing suspended silt particles, had caused the formation of lenses reaching almost to the gravel in most of the 29 filters. Sand handling by the above methods was slow and under present-day conditions outmoded, since it required a great amount of labor.

Uprating of the McMillan filter plant required more frequent and more thorough filter washes than in past operations and the procurement of modern sand cleaning and raking equipment became necessary. Six machines of the self-propelled type, five for dry-bed operation and one for wet beds, have been procured and placed in operation. Figure 4 shows the dry-bed type machine in operation. The machine is electric-motor-driven and operates in only the forward direction. The screw conveyor attached to the front pushes the sand to a center receiving box where it is picked up by an hydraulic ejector and carried to the separator mounted on top of the machine. All sand and water impinges on a circular vertical plate attached to the separator cover. Agitation within the separator cleanses the sand grains as they settle to the bottom where the sand is drawn off through a hose and

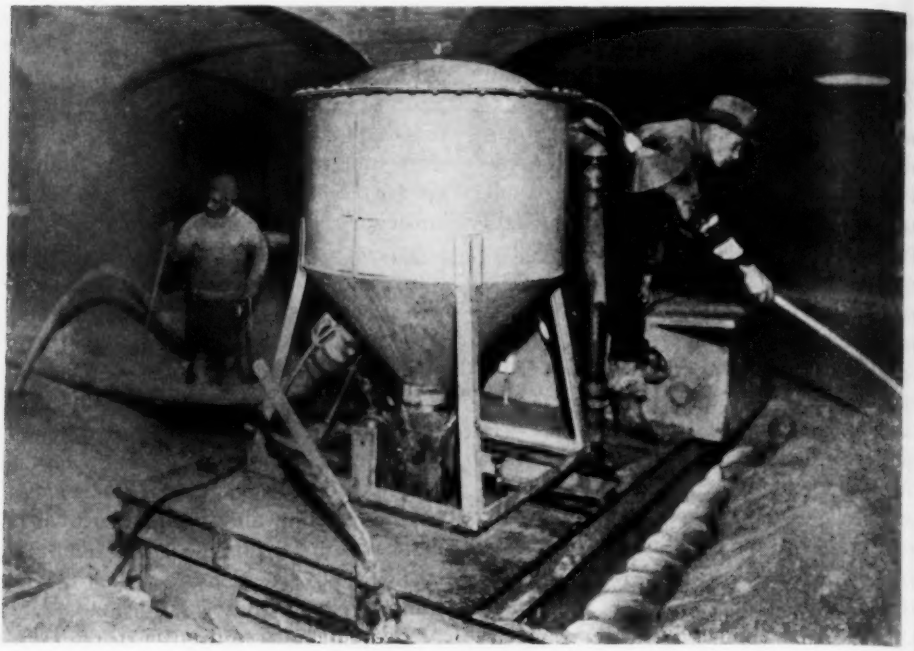

FIG. 4. Electric-Motor-Driven Dry-Bed Machine in Operation

deposited immediateiy back of the machine. All water and the suspended dirt are drawn off near the top of the separator and are carried through hose lines to disposal. At the present time the dry-bed machines are being used to excavate the surplus 10 to 12 in. of sand, which are not required under the new operating practice. The sand thus excavated is transported hydraulically to a remote storage area.

Each machine operates at approximately 7 cu.yd. of sand removal per hour. In the future, it is proposed to deep-clean all of the beds down to gravel with the same type of machine. Electric power underground distribution lines of 3-phase, 4-wire construction have been installed across the tops of all filters, with accessible power taps into the filters, for the purpose of operating the dry-type sand-washing machines. A small tractor and some machine-drawn filter rakes have been added to the list of sand-handling devices. These are used to break up the "schmutzdecke" which forms on the filter during its operation. After raking, the filter can be placed in operation at rates almost as high as obtained by a sand wash.

To meet the anticipated high sustained and peak hourly rates, new and larger capacity pumping units are necessary to keep up with the uprated conditions being provided in other elements of the McMillan plant. Two of the three present 50-mgd. pumps at McMillan main low-lift pumping station are to be replaced during the spring of 1945 by vertical adjustable blade units each capable of 75-mgd. delivery. The new units are especially designed to operate with the McMillan

open reservoir drawn down about 15 ft. in the event of an emergency. On the opposite side of the open reservoir from the pumping station, an adjustable-blade impeller type pump has been obtained for installation in the aqueduct tunnel shaft through which all water flows to McMillan. By lowering the head in the shaft, the gradient in the Washington City Tunnel is steepened to such an extent that the flow can be increased from the normal 75 to 125 mgd. The characteristic curves for this new unit indicate that at a delivery of 125 mgd. against a total dynamic head of 25 ft., the efficiency is 77.5 per cent. A feature of this new pump is that its 1,000-hp., 2,300-v. synchronous motor will be started across the line. Starting across the line will be at practically no-load conditions, as the adjustable impeller pump blades will be in their closed or flat position during starting operations and the pumping load will not come on until the blades begin to open. The local power company permitted this method of starting because the kilovolt-ampere inrush was less than 300 per cent of the normal full-load requirements. In addition to hand control, the new unit will be equipped for automatic operation over a 4-in. rise and fall in elevation of the McMillan open reservoir. The normal operating controls are located in the McMillan low-lift pumping station.

Filter Operations

The use of mechanical sand washing and sand raking equipment at McMillan has made it possible to maintain approximately 23 to 25 of the 29 filters in service during the past summer months of high consumption. The other filters were either in the process of being drained for washing or raking or of being filled. Individual rates generally varied from 1.5 to 5.5 mgd. and their summation was readily checked against the total metered plant output to the city. In the past, head losses through the filtering media and collecting piping were allowed to reach a maximum of 6 ft. and, of course, filtering rates decreased as the losses of head increased.

During the past summer, the filter index, the quotient obtained by dividing the total filter head losses by the total amount of water filtered in million gallons daily, was maintained at approximately 0.5. When this index approached 1.0, filtering output diminished rapidly in plant ability to meet hourly demands. The above noted index indicates that the filters were generally in good condition. Another reason for the 0.5 index was that the depth of water on the filters had to be reduced by 2 ft. and, consequently, filter head losses had to be corrected by a like amount so that the output could be maintained. Coincidentally, filter runs were reduced, as it became necessary to drain down and process a filter when a head loss of 3.5 to 4.0 ft. occurred.

Processing was generally by raking the sand in two directions or by sand washing. Since only the dry-type sand washers were initially secured, they were operated on a three-shift basis during the past winter and early spring and 17 of the 29 filters were washed to an average depth of 16 in. After such a thorough sand washing operation, several of the filters have been mechanically raked four or more times between washings and would possibly give satisfactory production through two additional rakings. The average rates of a group of nine filters in use during the last three or four rakings was 3.98 mgd. and their aver-

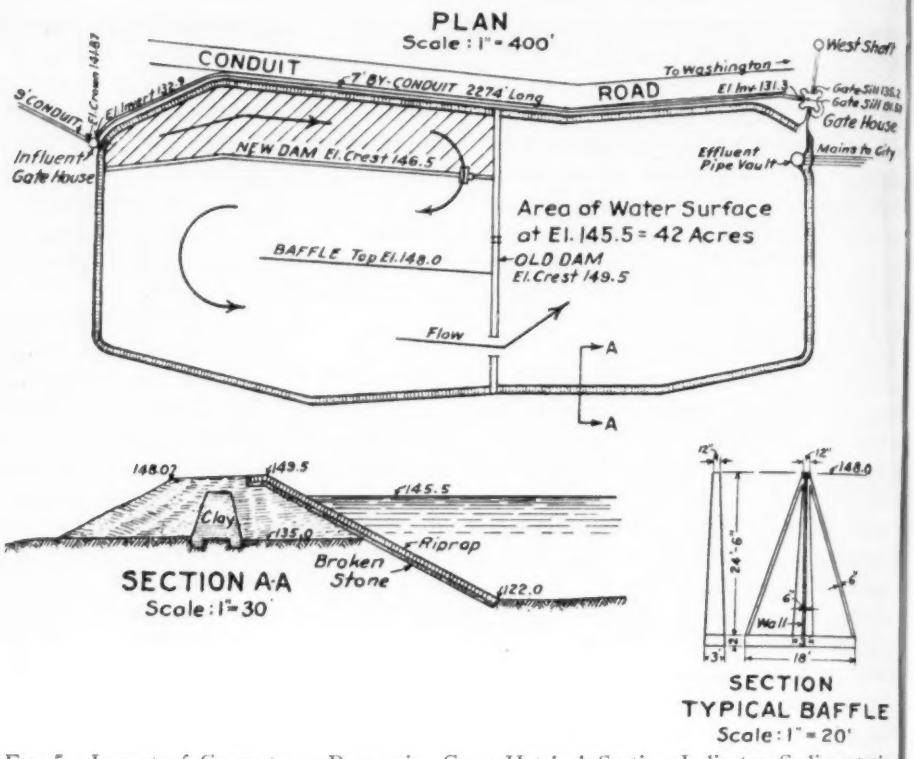

FIG. 5. Layout of Georgetown Reservoir—Cross-Hatched Section Indicates Sedimentation Basin Where Most Settleable Solids Drop From Coagulated Water

age run duration was 36.3 days. Their average head loss prior to raking was 3.95 ft. and the initial head loss after raking decreased to an average of 1.10 ft.

Heretofore, filtering capacities have been limited by methods of cleaning and/or raking the filtering media, by hydraulic inefficiencies of the structures and by curtailed flow of water to the filters. These three bottlenecks are being removed to such an extent that the filters will be capable of operation by next summer at rates approximating 20 per cent in excess of past uprated performances.

The highest filtration rates occurred during the period June 1943 through September 1943, with an average of 95.85 mgd., a maximum daily rate of 111.40 mgd., and a maximum hourly rate of 151.68 mgd. The latter figure indicates an approximate individual average filter rate of 6 mgd. as of this one-hour period. This figure is not considered unattainable as a maximum output for short periods. A sustained production of 125 mgd. is the present goal on the basis of not exceeding proper safeguards in the maintenance of equipment and facilities.

Coagulation and Sedimentation

During the first seven years of the McMillan plant operations, when the water consumption averaged under 60 mgd., it was customary to shut off the conduit river intakes during periods

when excessive turbidities, ranging in the neighborhood of 1,000 to 2,000 ppm., prevailed in the Potomac River. The three storage reservoirs on the raw water supply would be drawn down in an effort to prevent abnormal silting on the filters. As consumption increased it became necessary to maintain the flow of water through the reservoirs and all water leaving Dalecarlia Reservoir was coagulated when the turbidity exceeded 75 ppm. Mixing was accomplished in the 2-mi. long conduit between Dalecarlia and Georgetown reservoirs. The latter was divided into sections, thus providing a sedimentation basin which could be drained as required. The water had a detention period of about five days in its travel through Georgetown and McMillan reservoirs. Turbidities were regularly reduced to from 10 to 20 ppm. and with the turbidity thus reduced the plant capacity could be maintained at the originally rated production.

A test run of the afore-mentioned "egg beater" pump and, incidentally, of the McMillan filters, was made during September 1942. Only normal treatment was applied to the water for coagulation and only regular cleaning operations were given the McMillan filters prior to the test, so that, when an average of about 100 mgd. was filtered through the plant, head losses in many filters built up to 5 and 6 ft. in a conspicuously short time. It was then obvious that increasing the supply to the plant by pumping alone could not materially uprate the McMillan plant and that additional coagulation was a prerequisite for all water filtered at the new and higher filter rates.

Since the greater portion of alum used for coagulation purposes is manufactured at the Dalecarlia plant, it was necessary to increase only the purchases of acid and bauxite to meet the required additional treatment, which now nearly parallels the alum application for water treatment at the Dalecarlia rapid sand plant. With rates up to 125 mgd., the mixing period is about 55 min., which is the time required for the water to travel from the Dalecarlia to the Georgetown Reservoir at a velocity of 3 fps. Metered rates approximating 125 mgd. have shown good floc formation entering the first section of Georgetown Reservoir and the effluent therefrom is quite free of turbidity but contains a small quantity of unsettled pin-point floc which settles almost entirely during the 24-hour period of sedimentation in this reservoir. Figure 5 shows the layout of Georgetown Reservoir with the first section shown cross-hatched to indicate the sedimentation basin where most settleable solids drop out of the coagulated water. Under uprated operating conditions the sedimentation basin will require cleaning two to four times per year. Some sedimentation will continue for approximately 48 additional hours in the McMillan open reservoir. These periods are based on total reservoir capacities and do not discount the dead spots within the reservoirs.

The graph in Fig. 6 indicates very clearly the pronounced reduction of turbidities in the applied water to McMillan filters, showing an average of approximately 2 ppm. during the past 22 months. Throughout this period the highest turbidity, 5 ppm., occurred in April 1944. This peak was caused by an experiment with reduced alum application in amounts known to be less than actually required for best floc formation and settling. The result was that the proper pH was not obtained for good floc formation and a smoky

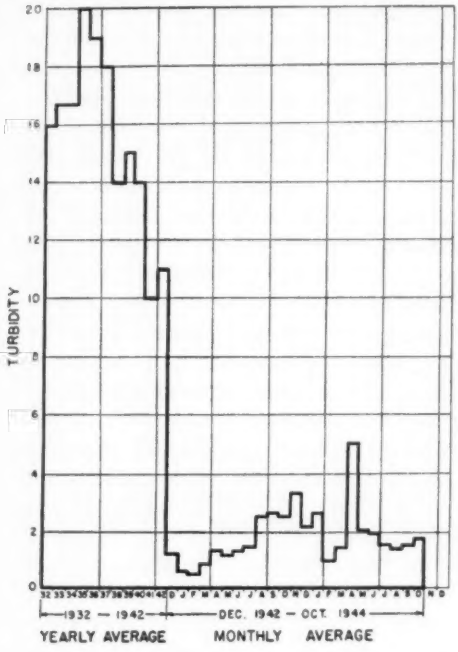

FIG. 6. Graph Showing Reduction of Turbidities in Applied Water to McMillan Filters

water carried over to the filters. The filter sand clogged rapidly, thereby reducing the time period of operation by several days. This trial during actual operations demonstrated that extended sedimentation periods could not be substituted for optimum alum dosage and that any economy derived from low alum application was offset by decreased filter runs.

Figure 7 shows graphically the increased alum consumption at McMillan during the past two years, indicating that the tonnage has trebled that of any prior year. The curve shows that unit alum application to McMillan water parallels that of the quantities applied at Dalecarlia, a rapid sand plant. Coagulation and settling were much better for McMillan treated water because the time of settling was about 25 times as great. The water thus clarified by increased coagulation has made possible the uprating of the McMillan plant and has improved the quality of the filtered water as indicated by the reduction in coliform indexes.

Conclusion

McMillan filter plant has often been referred to as a "sleeping giant," indicating that it was capable of greater production if and when it was awakened. The procurement of modern sand washing equipment and the alterations made in plant structures and appurtenances have initiated the awakening and given evidence of further uprating possibilities. Tribute is made to the designers who built the rugged features into a plant that has given excellent performance for nearly 40 years and is capable of increased production with relatively minor additions and alterations. The capacities built into the filter underdrains, conduits, tunnels and settling reservoirs

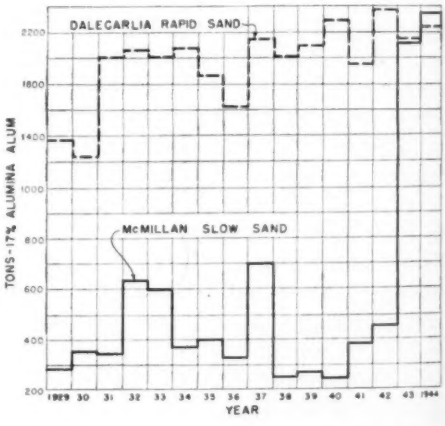

FIG. 7. Graph Showing Increased Alum Consumption at McMillan Reservoir During Past Two Years

are of utmost value in this day when higher production rates are demanded to avoid capital improvements.

In uprating the McMillan slow sand plant, it has been found essential to coagulate the raw water to a greater extent than would be necessary for a rapid sand plant, so that the water is in condition for filtering at high rates.

With new pumps scheduled for installation in the near future and other features still to be developed and installed, the sustained capacity of McMillan is expected to be increased approximately 66 per cent over its previously rated output. This will be an increase of from 75 to 125 mgd. and it may even be possible to carry a peak load of 150 mgd. for short periods.

Uprating the capacity of the McMillan slow sand filters has not been as simple as the foregoing recital might seem to indicate. Particularly difficult were the physical improvements which had to be and were made with the minimum use of critical materials. The effort has been under continual study and development by the staff of the Washington Aqueduct water supply system for almost eight years. The District of Columbia, which furnished the funds for the improvements made thus far, has profited from the increased filtration plant capacity which has been obtained at a much lower cost than would be incurred by the construction of new facilities of the same capacity.

The Conservation of Water Resources and Its Progress in Maryland

By Joseph T. Singewald Jr.

Director, Department of Geology, Mines and Water Resources

Presented on Nov. 9, 1944, at the Four States Section Meeting, Philadelphia, Pa.

THE people of the United States were long fortunate in having an expansible frontier beyond which were vast virgin natural resources. There was no consciousness of measurable limits to natural resources. But even while the frontier was still expanding, scientists became conscious of the existence of limits to our natural resources and of the need for conserving them. A popular conservation movement was first formally inaugurated by President Theodore Roosevelt in 1908, at the notable White House Conference, which resulted in the appointment of a National Conservation Commission. Even Congress had not yet become aware of the necessity of conserving our natural resources. It denied the National Conservation Commission a modest appropriation of $25,000, and prohibited the scientific bureaus of the federal government to do work for the commission. Despite this discouragement, the crusade was continued.

Soil and Forest Conservation

Since 1908 soil conservation and forest conservation have made appreciable headway. The loss of soil through erosion and the depletion of forest acreage is a phenomenon obvious even to the casual eye of the layman. Soil conservationists have measured the amount of soil that is being carried away by our streams, and they have measured the number of acres of fertile farm land that have been rendered worthless by this process. Foresters have determined the number of acres of forest land that have been denuded of their trees, and they have estimated the amount that the annual cut of timber exceeds the annual growth. They have told us in mathematical quantities by how much we are depleting our forest resources every year. Yet with the advantages of such visual evidence and such a wealth of quantitative proof, soil conservationists and foresters have only been able to slow down the rate of exhaustion of soils and forests. They are far from achieving a balance between nature's secular rate of soil formation and man's temporal rate of soil erosion and between nature's slow rate of forest growth and man's rapid rate of forest cutting.

There is, however, public consciousness of the fact that soils and forests are being used at a faster rate than they are being renewed, and that we have piled up a huge national debt in soil and forest that will be even more difficult to liquidate and that will have greater effect on our future economic well-being than will our astronomical national monetary debt. As a last re-

sort the monetary debt can be repudiated, but the soil and forest debt cannot be shaken off so simply.

Conservation of Unreplenishable Mineral Resources

Less known to the public is the depletion that our mineral resources have undergone. The requirements of World War I first brought forcibly to public attention the incompleteness in kind and the limitations in quantity of our mineral supplies. It was not until then that much headway was made in taking stock of our mineral resources and in recognizing the need for conservation of that stock. Under the auspices of the War Industries Board, during the first world war, our mineral resources and their inadequacies were thoroughly inventoried for the first time. The far greater demands for mineral products of the present more highly-mechanized war have even more sharply focused attention on the limitations of our mineral supplies, and they have again and even more thoroughly been inventoried by various federal war agencies. These appraisals point unmistakably to the urgent need for utilizing without waste and for conserving wisely our mineral resources.

It is not difficult for the man on the street to understand that when 1,000,000 tons of iron ore are removed from a 10,000,000-ton iron ore deposit, the content of the deposit is reduced to 9,000,000 tons. He will concede that if this process is repeated every year for ten years, at the end of ten years that iron ore deposit will be exhaused. It is less easy to make him understand that, although in the past the geologist and mining engineer have always been ready with another 10,000,000-ton deposit of iron ore to take the place of the exhausted one, the time will come when the geologist and mining engineer will not be able to furnish a substitute. And even if he will finally admit this fact abstractly, it is still more difficult to make it a matter of personal concern to him. Consequently, no headway has been made in slowing down the rate of exhaustion of unreplenishable mineral resources. On the contrary, the exhaustion rate of these mineral resources is continuously accelerating.

Conservation of Water Resources

Less obvious to the public is the depletion of water resources. As it is an obviously replenishable resource, the public has been prone to look upon water as a resource that is inexhaustible. As a matter of fact, the public has not regarded water as a tangible asset, but as something so readily and abundantly available that everyone is free to take it where he finds it, to take as much as he cares to and to use it for whatever purpose he pleases. The early settlers in the more arid regions of the West soon learned that this is not true of surface water and such communities soon regulated the use and appropriation of surface water as a public asset subject to public control. Later on, as ground waters were pumped in increasing quantities, the people in these regions also learned that ground waters were limited in quantity and in their rate of replenishment, and regulation of the use and appropriation of ground waters was initiated, based on the policy that they constitute a public asset subject to public control. Necessity more slowly forced such policies upon the people of the eastern United States. Depletion and inadequacies of water resources were experiences that did not confront them so quickly.

That the frequency and amount of rainfall varied from year to year, that the amount of water flowing in the streams varied seasonally and from year to year, that some wells yielded more water than other wells and that water levels were falling, were still phenomena without consequential significance. The thought never occurred that some day the amount of water flowing in a stream might not be equal to the demands for water in the area served by that stream, that some day the amount of water that could be pumped from a well would permanently be less than the amount of water that was being pumped, and that the drilling and pumping of new wells would yield no result other than decreasing the quantity that could be pumped from other wells.

There came a time when greatly increased density of population locally, and increasing industrial development locally, caused demands for water that exceeded the rate at which water was being replenished in those areas. Communities had to extend their water supply systems to embrace increasingly more distant streams. The yield of wells in some areas began to decrease and the larger quantities of water demanded could no longer be obtained by simply drilling more wells into the same aquifers. Overpumping was impairing the quality of the water by drawing extraneous waters into the aquifers. Eastern states were finding it necessary to control the use and appropriation of surface and underground waters. Some states have been more progressive and wide awake than others in both time and scope of action in meeting these impending inescapable problems. Seldom were these problems faced in a practical way until acute cases of shortage and depletion had arisen that forced public action. Remedial measures were developed and applied only after symptoms were pronounced and acute crises had been reached. Even the more forward looking states did not practice the "ounce of prevention," and the less far-sighted states were slow in applying even the "pound of cure."

Principles Governing Control of Water Resources

The principles that must govern the proper and wise use of water resources are simple and obvious. It is axiomatic that in the long run water resources cannot be drawn upon at a rate greater than the rate at which they are replenished. It is certain that the demands for water will not even remain constant but will increase progressively with time. Prudent regard for the future, consequently demands that the maximum rate of withdrawal at any time shall not exceed the rate of replenishment. It is a public duty and responsibility, therefore, to inventory the existing resources of surface and underground waters, and to measure quantitatively their rates of replenishment.

Control of Surface Waters

The application of these fundamental principles to surface water is relatively simple. It is accomplished by stream flow measurements. Continued over a sufficiently long period of time, the records of such measurements tell what quantities of water will be available under probable minimum drought flows of streams and what quantities are available under conditions of normal or average flows of streams, and by what amounts these quantities will be exceeded under probable maximum flood flow of streams. The

amount of water that is being withdrawn from streams at any time is readily determinable. Routine engineering calculations will tell the cost of salvaging for use the remainder which is running to waste by being emptied into the sea. It is an arithmetical problem of the capacity and cost of dams and reservoirs which has an indefinite number of solutions within the range of zero salvage and 100-per cent salvage. The practical limitations of acceptable solutions are determined by economic considerations.

It must be recognized, however, that there are disturbing variables in the equation that render the problem more complex and the answer less certain and less constant than just described. The flows of streams are influenced by the amount of deforestation and by the amount of soil erosion, not only in their own drainage basins, but also regionally and by changes in the level of underground waters. These same factors exert a profound influence on the rate at which reservoirs fill with silt instead of with water and hence on the effectiveness of measures to salvage the overflow of streams. Conservation of natural resources is not a separate and independent problem for each resource, but the conservation of each resource is dependent upon the practice of conservation in other resources. This is notably true of streams.

Control of Ground Waters

More complex and less obvious are the principles that govern the proper and wise use of ground water resources. As in the case of streams, nature alone determines their rate of replenishment. In this case, nature has also provided the storage reservoirs underground. Man cannot increase the size or the number of these reservoirs as he can with surface waters. One cannot as simply determine how much of the water being withdrawn represents current replenishment and how much represents actual depletion of the accumulated storage by merely measuring the number of inches or feet the water has fallen below the crest of the dam. The problems in this case are intricate geological and hydraulic problems. The solution requires detailed and exhaustive stratigraphic investigations. It requires observing the effects of pumping on static water levels of the wells being pumped and at more distant observation wells. It requires determinations of the physical properties of the aquifers—their thickness, their permeability, and artesian heads. This intricate problem is likewise influenced by extraneous factors in other fields of conservation, such as forestation and soil erosion, because of their effects on water levels. Geologists have tried to solve these problems as purely geological problems, but have been unable to attain the required quantitative precision. Engineers have tried to solve these problems quantitatively as purely engineering problems without the aid of geology, but the exactness of their results has been misleading instead of reliable. The failures and inadequacies of these two independent approaches to these problems have resulted in the development of a new group of specialists, engineers trained in geology and geologists trained in engineering, who are making rapid and remarkable progress in mastering the principles controlling the storage of underground waters and the safe rate at which they can be withdrawn. Progressively advancing with the development of this science as a quantitative science have been the recogni-

tion of the need for public control of the withdrawal of ground waters and the exercise of such control.

Control of Wells and Well Drilling

Logically supplementing public control of ground water is public control over the drilling of wells, over the conditions of wells while in use and over the conditions under which wells may be abandoned. Progress at varying rates in different states is being made in this direction also. Unfortunately, many states have not yet become aware of their needs and still exercise no control whatever. The quality of ground waters is not the same in all aquifers in the same area. One aquifer may contain remarkably pure water. Underlying and overlying aquifers may contain waters with large quantities of substances that render their use objectionable and even unfit for particular purposes. The earth is a multiple compartment vessel with waters of different character and quality stored in different compartments. He who drills a well punches a hole through the walls of these compartments. It is only reasonable that he who is permitted to punch such a hole shall be required to do so in a manner that will prevent the contents of one compartment leaking into and changing the character and quality of the contents of other compartments. Moreover, running over the surface of the earth and precolating downward into the earth are contaminated and polluted waters. He who punches a hole in the top of this vessel should also be required to protect the contents of its compartments from infiltration of such impure waters. The owner of the well who is permitted to withdraw the contents of one of these compartments should also be required to maintain the well in such condition that there is no mingling of objectionable surface water with the contents of the compartments and no mixing of the contents of different compartments. He should also be restricted to such withdrawals as are utilized by him. Permitting unrestricted flow of flowing artesian wells and continuous pumping of wells at rates in excess of needs are inexcusable, wantonly wasteful practices. Extravagant misappropriation of ground waters is a great public disservice that should be promptly and decisively curbed. It is not unreasonable to require, when a well is abandoned and no longer useful to the beneficiary, that he shall protect the valuable contents of these subsurface compartments by permanently patching and sealing the holes that have been punched for him by the well driller. It is incumbent on the government to protect the people's water resources by imposing the obligation of such prudent safeguards upon those who are permitted to appropriate these waters to their own use.

The Maryland Policy

There is a fundamental distinction that is commonly overlooked—that a policy is one thing and that the implementation of the policy is wholly separate and independent of the policy. No matter how excellent a policy, it is no more useful or effective than its implementation. The declaration and adoption of a conservation policy for water resources does no more than indicate the direction of action to be taken. Conservation of water resources is accomplished only when the policy is implemented by adequate measures to put it into effect and by adequate financial support of those

measures. Maryland has formulated a water conservation policy, but has not yet implemented it.

The Maryland Legislature of 1896 established a State Geological and Economic Survey charged with "an examination of the geological formations of the state with special reference to their economic products" and the preparation of reports "which shall embrace both a general and a detailed description of the geology and the natural resources." Building stones, clays and ores are cited as specific examples of economic products, but water is not. In the discharge of the general mandate, the survey in 1918 published a report on "The Surface and Underground Water Resources of Maryland" which still represents the only published report available on this subject. Moreover, the budgets of the survey since 1918 have not been adequate to permit more intensive investigation of the water resources or the systematic accumulation of much additional unpublished information.

That the water resources of Maryland are not inexhaustible and unlimited in amount was brought to the attention of the people of Maryland as a consequence of the drought of 1930. The legislature of 1931 created a commission to review the underground and surface waters of the state and to determine the most effective plan "to preserve and allocate such water supply resources for maximum public benefit and use." The commission published a report in January 1933 setting forth "Recommendations as to Policy, Legislation and Methods of Financing for the Preservation of the Water Supply Resources of the State of Maryland." These recommendations were enacted into law by the legislature of that year. The cover of that report carries the quotation from Benjamin Franklin: "When the well's dry, they know the worth of water." The 1933 Act declared it "the policy of the state to control, as far as practicable, the appropriation or use of surface and underground waters," and created the Water Resources Commission of Maryland to carry out the policy. In 1941, the legislature formed the Commission on Geology, Mines and Water Resources and delegated to it the powers and duties exercised by the superceded Water Resources Commission. Since Jan. 1, 1934, it has been unlawful to appropriate or use any waters of the state, surface or underground, without the consent or permit of the commission except for purely domestic purposes. In granting a permit, the commission may impose such restrictions as to character, amount, means and manner of such use as it deems necessary to insure the safety and welfare of the people of Maryland. Despite the importance of this policy and the scope of the responsibilities placed upon the Water Resources Commission, no regular budget provision was made for the effective implementation of the policy. The preliminary commission was granted $5,000, and the Water Resources Commission carried on with the left-over balance until 1938 when the Board of Public Works made an additional $3,000 available. On the eve of its dissolution in 1941, the Water Resources Commission was allowed a budget of $2,500 for 1942 and 1943 to be expended subject to the approval of the Board of Public Works. When the Water Resources Commission was merged into the Department of Geology, Mines and Water Resources in 1941 and its responsibilities transferred to that department,

no cognizance of the transfer was reflected in the budget of the department. The rapidly mounting demands on the ground waters around Baltimore resulting from the expansion of industrial plants engaged in war work brought a long existing problem of shortage and contamination of such a crisis that late in 1942 a special allowance of $5,000 was made by Governor O'Conor and the Board of Public Works to begin an intensive investigation of the ground water resources of the Baltimore regional area. This appropriation was augmented in 1943 by an additional appropriation of $3,400 by the Board of Public Works and $3,500 by the city of Baltimore to carry this investigation to the close of the fiscal year ending June 30, 1945, the estimated date of its completion. It remains to be seen whether the department's future budget will provide for the continuance of such work in the rest of the state as a systematic and orderly program, or whether it will be restricted to intermittent special allotments procurable only to meet crises such as that in the Baltimore regional area.

The Water Resources of Maryland

The physiography and geology of Maryland are such that in the region lying west of the "fall line," a sharply defined physiographic and geologic boundary running through Washington, Baltimore and Havre de Grace, the most abundant and accessible water resources are the surface waters; whereas in the region east of the "fall line," comprising the Tidewater counties, the resources of surface water are more limited and ground water resources must be depended upon to a greater degree.

Inventory of Surface Waters

Much progress has been made in inventorying the surface water resources of Maryland. The Geological and Economic Survey during the 45 years of its life, gave support to the maintenance of stream-gaging stations. In addition, communities and industries within the state have been contributing to the support of stations on streams which they are utilizing. As is the practice in the United States, these gaging stations are operated under a co-operative agreement with the United States Geological Survey which contributes a sum equal to the contributions of state and intrastate agencies. The federal government also maintains independently a number of stations in the basin of the Potomac River. The Water Resources Commission's 1938 report lists 34 stream-gaging stations in active service. By 1943 the number had been increased to 39. During 1944, the Department of Geology, Mines and Water Resources solicited the operating support of five additional stations from intra-state agencies, so that there are now 44 active stations. The annual operating cost of these stations is $23,565, of which the state of Maryland pays $5,000 and intra-state agencies pay $4,550, the remainder being contributed by the federal government.

The annual flow records of Maryland stream-gaging stations are contained in the Water Supply papers of the U.S.G.S., but it requires tedious and time-consuming search to make them available for use. Part of these records were summarized in 1940 in a joint report of the Water Resources Commission and the State Planning Commission on "Flow Data and Draft Storage Curves for Major Streams 1929–1937." A compilation of all

Maryland stream flow records has just been published by the Department of Geology, Mines and Water Resources.

Gratifying and commendable progress has been made in inventorying the surface water resources of Maryland. This information is now available to those having need of it—to communities and industries who require the waters and to the commission that controls their use and appropriation. Maryland not only has a sound policy for the control of these waters, but has gone a long way toward its adequate implementation. The job is not done, however. Not only must existing stations be continued, but additional stations should be installed to complete the inventory in order to anticipate forseeable near future needs and less evident needs of the more distant future. The Department of Geology, Mines and Water Resources, in consultation with the Maryland Department of Health and the U.S.G.S., prepared a list of 24 additional stations that are needed for community water supplies, sewage and other waste disposal, and for more complete and more uniform coverage of the streams of the state. Five of these stations were put into operation in 1944.

Inventory of Ground Waters

Much less progress has been made in inventorying the ground water resources of Maryland. An immediate state-wide need is a census of Maryland water wells. An initial census of this sort is contained in the 1918 report of the Geological and Economic Survey, but these records are too incomplete and are now too old to furnish information on which to base the kind of technical and quantitative advice that is expected today. A closely related state-wide need is the establishment of observation wells for regular periodic measurements of fluctuations in the static water levels. Not even a beginning has been made in the gathering of such information. Yet the Department of Geology, Mines and Water Resources is called upon repeatedly for such information and to answer questions depending on such information. Such wells will have to be established and their behavior recorded over a period of time in the Baltimore regional area before that investigation can be considered completed and before the commission can properly exercise the controls with which it is charged over the further use and appropriation of the ground waters of that critical area.

Fortunately, the demand on the ground water resources over most of the Maryland coastal plain will not exceed for a long time to come their rate of replenishment or the ultimate safe yield of the water-bearing sands and gravels. Locally, however, the danger point has been approached and even passed. In 1933, the Water Resources Commission estimated the consumption of ground waters in Maryland to be less than 14 mgd. In 1944, the consumption of ground water in the relatively restricted industrial area around the port of Baltimore is at least 40 mgd. Since Baltimore City has a public water supply from surface waters, this situation has been serious only for the industries depending on these ground waters. Yet the state and also Baltimore City have recognized the seriousness of this situation and have provided for an investigation of the water resources of the area that is now in progress. More directly affecting the population itself is an existing water shortage in the town of Solomons Island in southern Maryland, re-

sulting from the large volume of ground water being pumped by the three large naval stations recently built in that vicinity. Postwar enterprises requiring large quantities of ground water are being considered for southern Maryland. With increasing population and industrial development in the Tidewater counties of Maryland, peak loads will be developed elsewhere, and other communities in these counties will be threatened with similar crises. The implementation of Maryland's water resources policy demands an immediately augmented program for extending the investigation of the Baltimore regional area into southern Maryland and from there across to the eastern shore.

Nothing has been done in Maryland regarding the registration of well drillers and the filing of well logs and other fundamental data concerning the wells drilled with the Department of Geology, Mines and Water Resources. There are no regulations requiring the protection of the aquifers from pollution and contamination during drilling or while a well is in use, or even upon the abandonment of a well. The Department of Geology, Mines and Water Resources is now considering regulations to cover these matters which will be proposed for legislative enactment to implement further the state's policy to preserve and allocate the ground water resources for maximum public benefit and use.

Erratum

Secretary's Letter to the Association Membership, Jan. 31, 1945

On pages 4 and 5 of the Secretary's letter to the members of the Association, the following statement appeared:

> "QUALITY OF WATER. The water must be clear, potable and safe for human consumption in accordance with standards adopted by the Treasury Department, June 20, 1945, for drinking and culinary water supplied by common carriers in interstate commerce and such revisions as may be made therein from time to time."

The date given above—"June 20, 1945"—resulted from a typographical error made in the office of the A.W.W.A. The date should read, "June 20, 1925."

The phrase, "such revisions as may be made therein from time to time," should be taken to mean that the terms of the United States Public Health Service Standard, promulgated on Sept. 25, 1942, govern [see Jour. A.W.W.A., **35**: 93 (1943)].

Practicing Ground Water Conservation

By G. J. Requardt

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Presented on Nov. 9, 1944, at the Four States Section Meeting, Philadelphia, Pa.

GROUND water is that immense body of water found at varying distances below ground level generally moving slowly toward the nearest stream.

Scattered farmhouses have wells which pierce the ground water level and which have a draft of several gallons a minute, hardly making a dimple in the ground water surface. The community well for a hundred houses cannot be said of itself to have an effect on the general depth of ground water level, although a number of community wells fairly close together may lower the ground water surface a small distance for a few hundred feet beyond the perimeter of the communities. The operation of these wells, however, would have less effect than the seasonal variation in rainfall over the area.

Numbers of large industries grouped near a city, each pumping steadily from scores of modern high-capacity wells, have the greatest man-made effect on ground water level. They may cause the surface of ground water to recede hundreds of feet; wells may go dry and pumping costs may go up. It is then that the value of this nearby source of water is realized and measures are taken to conserve it.

Ground water ordinarily is pure and uncontaminated. Its mineral content is easily corrected so that the water can be made suitable for potable and industrial uses rather inexpensively. We have learned that ground water must be kept in its natural state and all man-made poisons and pollutions must be prevented from percolating downward and mixing with it.

Conservation by Limitation of Use at Sparrows Point, Md.

The great tidewater plant of the Bethlehem Steel Co. near Baltimore occupies hundreds of acres on the river-front at Sparrows Point, Md. The company operates three separate water supplies and obtains a small amount of water from the city supply. Large quantities of salt water are used for cooling and quenching purposes. About 20 mgd. of fresh water have been obtained for a number of years from some 32 wells, for manufacturing purposes. There is a smaller number of wells which are operated for the potable water needs of the plant.

The company pumps about 170 mgd. of brackish water containing about 4,000 ppm. of chlorides. This water is not suitable for steel manufacturing since it would quickly corrode and etch the rolls. Until 1942 industrial fresh water was obtained from 32 wells of from 200- to 900-gpm. capacity each, many of these being in continuous operation. The rock line at Sparrows Point is about 650 ft. below the ground

surface and it has been calculated that ground water pumped by Bethlehem and other industrial plants in nearby areas has, for the last several years, amounted to about two and a half times the rain water on the catchment area.

The record of the lowering of the ground water table at the plant because of the operation of wells has been:

Year	*Feet Below Ground Surface*
1898	10 to 15
1917	15 to 60
1937	60 to 110
1940	70 to 153

With the drop in ground water level and its extra pumping costs it was found that there was an increase in chloride content. Some of the wells in 1937 produced a water with 10 ppm. of chlorides, whereas in 1941 the chloride content had risen to 210 ppm.

Because of the lowering of the ground water level and the increasing pumping costs, greater trouble with chlorides and the prospect of large increases in steel manufacturing due to the war, the company, in 1941, with its consulting engineer, Dr. Abel Wolman, intensely studied the situation. Surface streams, like the Patapsco, Gunpowder River and Deer Creek, were investigated. It was felt that a new source of water up to a capacity of 50 mgd. should be procured. Such a large amount of water, if taken from a stream, requires a minimum flow 20 ft. wide and 2 ft. deep flowing at a velocity of 2 fps. Such a stream in Maryland would have a watershed area of about 300 sq.mi. If the stream were regulated some 75 sq.mi. of watershed and an impounding reservoir of several billion gallons capacity would be required. A long transmission main of 60-in. diameter would also be required. Distances, capacities, difficulties in procurement of rights-of-way and costs made the development of a surface water supply look unattractive. Such a large quantity of water could not be obtained from the municipal supply of Baltimore. That supply at the time was furnishing some 165 mgd. to the city, with a subsequent rise in 1943 to 180 mgd., whereas the existing source of the supply had a safe capacity of only 148 mgd.

Some 6 mi. away from the company's plant there is the Back River Sewage Treatment Works of the city. The effluent from this plant of some 105 mgd. is stable, fairly clear and ordinarily contains a not unreasonable amount of chlorides. Experiments and investigations were conducted indicating that the turbidity and B.O.D. of the effluent could be satisfactorily reduced with alum, flocculation and sedimentation; that the chlorides could be reduced by controlling the sewage effluent from meat packing, soap manufacturing, hide pickling and the salty discharge from water softening plants; also that the seepage from the harbor into low-lying sewers could be reduced. Costs were investigated and it was found that an industrial water system, whereby the sewage effluent was utilized, would be satisfactory for steelmaking purposes, since previous tests had shown the etching of the surface of rolls was not serious if chlorides were kept below 175 ppm.

The firm of Whitman, Requardt and Associates was directed to design the new industrial water system with a capacity of 50 mgd. and consisting of connections to the final basins of the trickling filters and the activated sludge plant of the city, flocculating and settling basins, control house, some 24,000 ft. of 60-in. transmission main, a storage basin of 74-mil.gal. capacity, a pumping station containing one 10,-

000- and two 15,000-gpm. pumps, a 750,000-gal. elevated tank and a complete new cast-iron distribution system throughout the company's plant.

The plant was rapidly constructed and put into operation on Dec. 5, 1942, and its operation has been consistently successful. It uses about 5 gpg. of alum with 15 per cent available alumina and produces a water with a B.O.D. of from 5 to 7 ppm., a turbidity of 10 ppm. and a pH of 6.9. By watching the chlorides in the sewage works, and by discontinuing treatment and using stored water at critical times, the chlorides in the treated water for steel making have been kept below 100 ppm.

After this new water supply was placed in operation and the draft on the wells at the company plant was reduced from some 15,000 to 3,500 gpm., it was found that the ground water level rapidly rose from about 150 to 80 ft. below ground surface and has stayed at about that level ever since.

The total cost of operation and fixed charges of the new water system is about one-half the total cost of the former well system. The new system will soon pay for itself.

Conservation by Pollution Control in Colorado

Water in Colorado is valuable and its conservation is studied intensely. Through the years large water supply irrigation systems have been built and laws have been written looking to the equitable and economical distribution of water to the city dweller, the small farmer and the larger manufacturer. Lands adjacent to irrigation systems carry water rights which are conveyed in the same manner as are property rights. A person using water is by law required to return what he does not use into the same watershed from which it came. Neighbors are jealous of their water rights and the improper use of water has been the cause of much conflict. Water percolating from irrigation canals, ditches and fields, in addition to rainfall, supplies the ground water system which is tapped by farmers' wells and which ultimately flows into nearby streams to supply other irrigation systems further downstream. Water is thus used again and again and no one is permited to spoil the water so that it harms his neighbor.

In 1942 the government decided to build a chemical manufacturing plant on some 20 sq.mi. of land about 6 mi. east of Denver and bordering the south branch of the Platte River. The problem of water supply for the government project was of high priority. The author's firm, in association with H. A. Kuljian & Co. of Philadelphia, as architect-engineers for the plant, applied themselves immediately to its solution.

About 30 mgd. of industrial and cooling water (100 acre-ft.) are obtained from an irrigation canal some 70 mi. long, fed by one of the upper collection reservoirs of the city of Denver. This canal connects to the project system through about 4 mi. of an enlarged and partly lined ditch. The water is settled in two artificial ponds and is then pumped through the plant system. Spent water is returned to the ponds for re-circulation, while contaminated portions are neutralized before being discharged into the sanitary system. Potable water to the extent of about 1.5 mgd. is obtained from the filtered water supply of Denver through 6 mi. of pipe connection. This connection, however, is large enough so that as much as 30 mgd. of water may be obtained at times when there might be a break in the irrigation sys-

tem or when the canal is frozen over. All of the water, including sewage plant effluent, except for a small amount consumed and evaporated, finds its way back into the underground water for use on adjoining properties and thence into the Platte, where it may again be used further downstream.

At this project there is a chlorine manufacturing plant with a production capacity of 100 tons daily. Chlorine is made from common salt by an electrolytic process. The main residual solution emanating from this manufacturing process is caustic soda (sodium hydroxide) which is a destructive long-lived caustic. This solution has a specific gravity of 1.5 and solidifies at a temperature of 50° to 57°F. As it cannot be readily and economically destroyed or changed into less dangerous compounds, it must be disposed of in such a way as to avoid danger by contact or by the contamination of the water supply.

Caustic soda finds a ready market for paper and soap making and for several similar industries, but such industries in Denver have no need for the large quantities which were estimated to be produced, and, because of the shortage of transportation equipment, its shipment to other industries elsewhere was precluded. It was therefore necessary to treat the material as a waste product and to dispose of it by permanent storage on the government land.

Besides the many specialists in the Chemical Warfare Service available for the solution of this problem, the advice and experience of Prof. R. D. George, head of the Department of Geology, University of Colorado, and of a number of engineers and chemists of the Bureau of Reclamation at Denver were obtained. It was decided to study the areas, soils, temperature and various factors of the ground water supply so that, in arriving at a decision on the construction of a storage basin, the ground water would be protected.

A brief survey of the area revealed a natural hollow where there appeared to be a suitable quality and quantity of fine top soil available. An outdoor laboratory was set up so that tests with the caustic solution under varying pressure heads and on different characters of soil and under various degrees of compaction could be studied.

Test pits indicated that the top soil averaged about 13 in. in thickness, under which occurred a wind-blown sand up to 10 ft. in thickness. Below this were unconsolidated sands, stones and clay of quite irregular depth. Several wells were drilled and ground water was found to be about 32 ft. below the average surface. Soil samples from about 20 test pits were tested and the temperature about 10 ft. below the surface was obtained.

It was proven by the laboratory that there were sufficient soils which were most readily responsive to compaction, these having from 25 to 30 per cent of clay. It was proven that compacted material formed a better medium than natural soil in place in the prevention of the movement of the solution. The experiments showed that at the junction between the material and the soil a compound was formed which created a highly impervious layer preventing the movement of the solution. In all but one of sixteen bottomless tubes driven into the soil the leakage was encouragingly limited. From one tube driven into an undisturbed layer and uncompacted, the caustic penetrated some 11 ft. 8 in. below the surface. The temperature of the ground 10 ft. below the surface showed it to be

quite uniform at 50°F. or below the congealing point of the solution.

The group studying this problem came to the conclusion that if certain precautions and methods were carried out in the design of an open basin the following safeguards would have been erected against the movement of the deposit of this waste product into the ground water stream. These safeguards and natural factors on the side of safety are as follows:

1. The depth of ground water, while widely variable, was at a substantial distance below ground surface. Most of the ground waters are in perched water tables with no particular outlets and there were not well defined continuous water tables.

2. The solution will penetrate very slowly through the prepared lining.

3. There would be the very probable formation of a retarding layer by chemical action between the caustic and the soil.

4. Low temperature conditions in the ground will cause a congealing or solidifying effect at 10 to 15 ft. below the ground surface, thus preventing further percolation.

5. The solution itself is naturally viscous and this will cause the penetration to be slow.

6. Lining material found at the site was favorable.

7. The basin selected for deposit of the waste material was near the center of the government land and thus there is a distance of several miles between the basin and private lands where wells may obtain a supply from the ground water system.

8. The average humidity of the atmosphere is about 48 per cent. This makes the air thirsty and it thus will not yield water to the solution. In fact, the atmosphere may steal water from the caustic and increase its density.

9. The caustic readily stratifies. The more viscous and less penetrating caustic goes to the bottom and will add to the sealing effect.

The basin roughly measures 1,200 ft. by 1,200 ft. or about 22 acres and was designed to hold a five-year output of waste product. Its first 10 ft. of depth holds about 100 acre-ft. and its second 10 ft. of depth holds 200 acre-ft. in addition. The construction of the basin was as follows:

> The top soil was scarified 5 in. in depth and all vegetation and roots were raked off. The scarified surface was then compacted. A lining material of sandy, gravelly clay or a consolidated mixture containing some 25 to 30 per cent of clay was then placed 12 in. in depth and compacted with sheepsfoot rollers. An additional 4 in. of this lining material was placed where the top soil was thin.

Consideration was given to concrete and asphaltic linings but they were discarded because the concrete would have been attacked by the solution and it was felt that the clayey lining would be successful and the use of asphalt would be an unwarranted expense.

One might think that the precautions taken in this case for the protection of the water supply were quite elaborate and so they would appear when viewed in the light of the carelessness displayed by many manufacturing concerns in this country which seem to have but little concern with the damaging of water supplies. The army felt it could take no chances in the situation and made the intensive surveys and studies of the problem before it adopted the plan described.

Progress Report on the Use of Copper Sulfate in the Control of Bacteriological Aftergrowths

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Prepared for presentation on Apr. 11, 1944, at the Illinois Section Meeting, Peoria, Ill.

BACTERIOLOGICAL growths in the Champaign-Urbana distribution system became so luxuriant that the continual sloughing-off was a source of continuous consumer complaint. Other complaints were because of decreased volume of water resulting from reduced carrying capacity of the service lines. It has not been unusual for the diameter of a ¾-in. service pipe to be reduced, by the build-up of these growths, to the size of a lead pencil.

At first the growth of iron bacteria appeared to be the one source of trouble. Iron removal was instituted in 1912, but, as the years passed and the growths of the iron bacteria family decreased three other groups were identified. These groups have been broadly identified as capsulated-ammonia and nitrogen-eating bacteria. (Dr. Max Suter identifies ammonia-nitrate as *nitrosomonas,* nitrite-nitrate as *nitrobactor,* and elementary nitrogen-organic nitrogen as *azotobactor.*) Whether these three groups had always been present and were not readily apparent because of the luxurious iron bacterial growths, or were of later development, is impossible to say. The presence of ammonia and dissolved nitrogen in the natural water in rather large concentration (4.5 ppm. NH_4) explains the presence of the three latter groups and indicates the probability that they have always been present.

In a study of this aftergrowth problem, Buswell and Suter report (1), "The former opinion was that the troublesome floc was mainly produced by iron bacteria with *Crenothrix polyspora* as the main representative. However, this organism has not been found in the distribution system or even on the filters, although it is common in the water coming directly from the wells. It does not seem to spread beyond the aerator. The iron organisms found in the distribution system include *Leptothrix ochracea, Gallionella ferruginea,* but *Siderocapsa* and *Siderococcus* are most common. In all, iron bacteria form only a very small part of the organisms present in the floc, because there is, as a rule, very little iron present in the water . . . which is in the ferric state owing to the relatively high proportion of dissolved oxygen . . . ferric iron cannot be used as a source of energy."

An exceptionally heavy chlorine dosage (26 lb. per mil.gal.) is maintained. This dosage is divided between prechlorination and post-chlorination, the result being an average residual of 1.80 ppm. in the finished water. This residual is determined through the use of modified ortho-tolidine. The ortho-

tolidine is added to the sample, kept in the dark and read at the end of ten minutes. This procedure was adopted to reduce to a minimum false color produced by nitrites present in the water.

The use of break-point chlorination as a possible solution has been eliminated as economically unsound. The water theoretically requires an application of approximately 27 ppm. of chlorine to reach the break-point.

Copper sulfate has been recorded as being used in the control of *Crenothrix,* and it was felt that, if copper sulfate had been effective in the treatment of *Crenothrix,* it would probably be equally effective in the elimination of other members of this same family. It also seemed reasonable to believe that if this treatment were effective in the elimination of iron bacteria it might be of value in controlling other bacteria and, in this case, the ammonia and nitrogen-eating group.

Experiments With Copper Sulfate

To maintain over 0.25 ppm. copper in the water would have exceeded the then existing standards of the U.S Public Health Service. The 1942 standards raised this limit to 3.00 ppm. This delayed the beginning of the treatment.

The hurdle was finally cleared when the Illinois State Department of Health and the Champaign-Urbana Public Health District approved the experiment on a full plant scale, regardless of the existing U.S.P.H.S. standards.

A measured portion of snow-grade copper sulfate was dissolved in a 20-gal. earthenware jar. The solution was siphoned from this jar through an orifice rigged on a float so that a constant head was maintained on the orifice. By experiment, an orifice size which would permit the siphoning of 20 gal. of copper sulfate solution every eight hours was determined. In this way satisfactory control could be maintained to meet all conditions by increasing or decreasing the amount of copper sulfate dissolved in the jar. The solution was fed into the filter plant effluent after chlorination and just before it entered the clear well.

The water in which the copper sulfate is being dissolved should be hot. This will reduce the amount of copper sulfate required to produce any given amount of copper in the finished water.

The treatment was started Apr. 18, 1940. The results were immediate—bad water complaints dropped from 66 in March to four in May. This seemed too good to be true and was thought to be a coincidence rather than the effect of the copper. The treatment was maintained, however, and by the end of the year, with eight and one-third months of treatment, the total number of bad water complaints for the year was the lowest of any year on record.

Still feeling that there might be an element of coincidence in these results, the copper treatment was stopped in February 1941 for two weeks. Bad water complaints came in almost immediately. They increased from four in January to 21 in February. The copper sulfate was immediately started again and this figure dropped to three in March.

The experiment of stopping the treatment for a short time proved beyond doubt that copper sulfate was the factor that was controlling the bacteriological aftergrowths under conditions as they exist in this particular distribution system.

It should be stated here that when the copper sulfate experiment was started, the solution was fed to the finished water and to the raw water

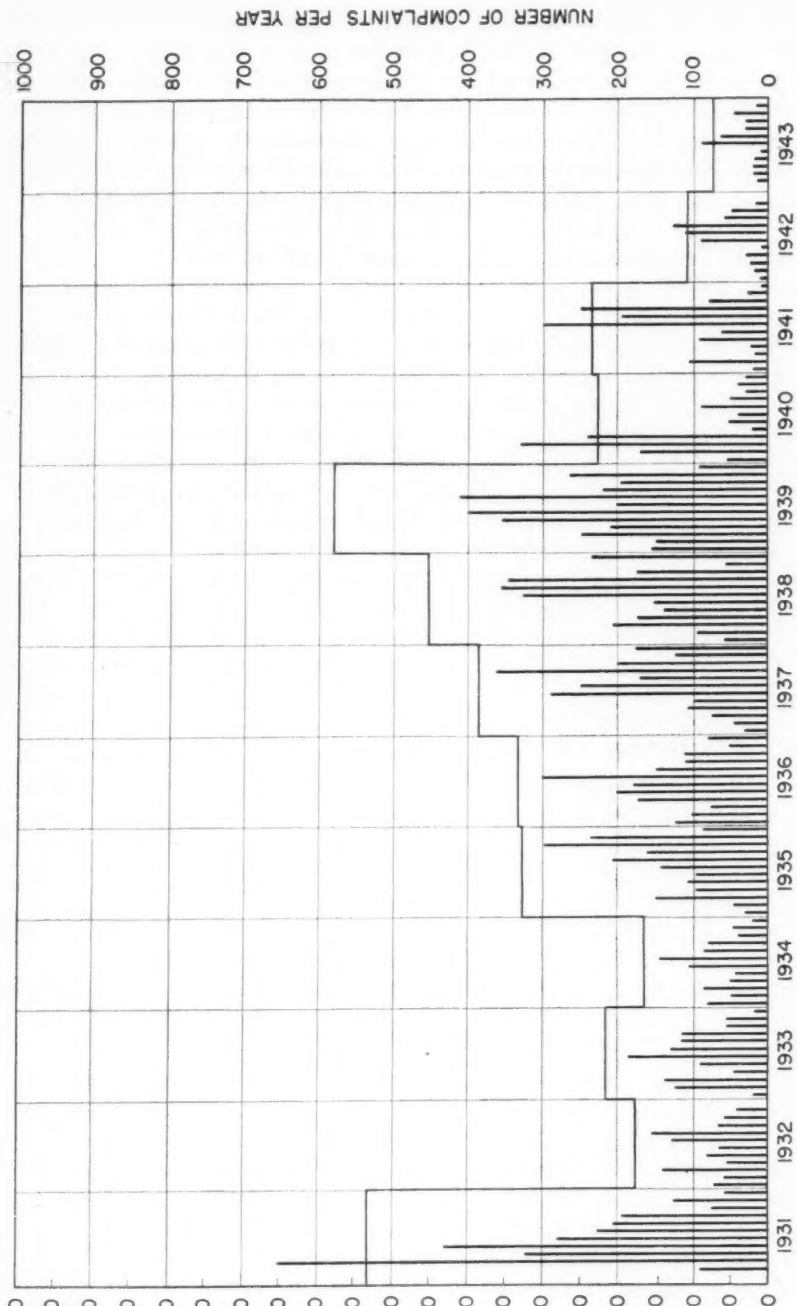

FIG. 1. Comparison of Bad Water Complaints by the Month—1931 to 1943, Inclusive

simultaneously, maintaining a copper residual of between 0.50 and 0.65 ppm. in the raw water.

The copper sulfate solution was introduced in the discharge line from the well field, at a point just before the water reached the aerator. The aerator was hoary with iron bacteria growths which hung down in long strings. Within a few days the color of these growths began to change from the usual brown into progressively darker shades, until it was approaching black at the end of the 114 days that this phase of the experiment was continued.

Before this experiment was started, iron tests run on the effluent of the plant averaged (for the month of March) 0.006 ppm. As this raw water treatment progressed, the filters were passing more and more iron until the effluent showed as high as 0.4 ppm. As there was no other factor that would explain this decrease in iron removal, the raw water treatment was stopped Aug. 10, 1940. The iron-removing efficiency of the filters soon returned to normal.

Due to its effect on the filtering media, this would indicate that copper sulfate should be applied to the influent of a filter plant only after careful consideration of the problem being dealt with and then only with extreme caution.

Complaints of poor water have been one of the indexes of the effect and progress of the treatment. On receipt of a complaint, a flush is made opening only those hydrants which would clear up the immediate complaint. No routine flushing or complete flushing is carried out during the period of this treatment. In this way data at hand are not affected by benefits that might be obtained with high-velocity flushes.

Another method of observation has been the inspection of toilet flush tanks. Those that had previously been thickly coated with this sludge are now clean, or nearly so.

In some of the pipes that have been removed from service or that have been opened, there is evidence of a tendency for the slime to change from a thick brown soft formation, to a dark sludge or black hard deposit.

Probably one of the most startling exhibits of the effectiveness of this treatment is in an upflow zeolite softening plant in one of the community's largest laundries. The growth of these bacteria in the zeolite was so rapid and luxuriant that masses were formed, channeling the zeolite, sand and gravel so that the softening process not only became ineffective, but the added buoyancy of the zeolite, due to this growth on the greensand grains, resulted in excessive losses of the material in backwashing. The only cure was a complete removal of the filtering media from the shells, thorough cleaning and relaying.

The following tabulation shows the number of times this rehabilitation was found necessary in the years indicated:

1939	27	(year before copper treatment)
1940	1	in September (copper treatment started in April)
1941	1	in September
1942	1	in October
1943	0	
1944	1	in January

Figure 1 shows graphically the tabulation of bad water complaints and gives a clear picture of the results from that angle. The vertical lines represent complaints by the month, the horizontal line the total for the year. When reviewing these data it should

Fig. 1. Comparison of Bad Water Complaints by the Month—1931 to 1943, Inclusive

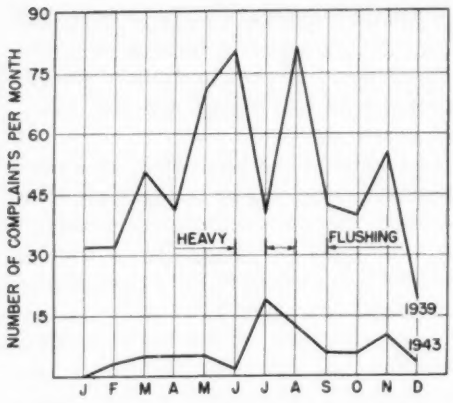

FIG. 2. Monthly Variation of Bad Water Complaints for Years 1939 to 1943

be kept in mind that up to the time the copper sulfate treatment was started, regular systematic flushing was routine. The procedure was to start in the vicinity of the pumping station and work toward the outlying districts, with never less than two hydrants open and at times three. Since the beginning flushing has been on complaint only.

It will be noted that in each year June, July, August and September data show a trend toward increased complaints. It has been found that when the filter rate exceeds 1.70 gpm. per sq.ft., the efficiency of iron removal drops rapidly. These are months of high demand and the filters are run well in excess of that rate. The complaints are probably the result of increased iron in the effluent of the plant, and for the purpose of the copper sulfate experiment, might fairly be eliminated from consideration in the study of the data. However, there is a constant decrease in the complaints received during these summer months as compared to the corresponding period of the preceding year, this decrease beginning with the commencement of the copper treatment.

It is of interest to note the length of time required for this treatment to have produced a fairly satisfactory level. The first year that could be called satisfactory was 1943, the fourth year of copper treatment.

Figure 2 shows a comparison of bad water complaints by the month for 1939, the year before the treatment started, and 1943 the fourth year of almost continuous copper application. The complaints have been very carefully noted and each one investigated, analyzed and recorded, if found applicable to the immediate problem.

For the purpose of checking the effect of the copper treatment, sampling points in the distribution system were established, from which weekly samples were collected at the fire hydrants for making chemical determinations. Experience has shown that samples collected from a house service are not representative and at times a house sample may differ greatly from one taken from a fire hydrant at the same location. Of all the sampling points so established, a recapitulation of what appears to be pertinent data from two points only is shown in Figs. 3 and 4.

Of all the chemical determinations made, only nitrites, chlorine residual,

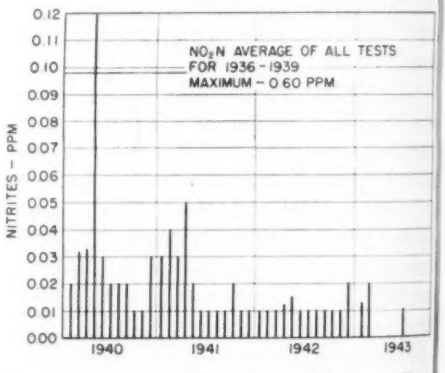

FIG. 3. Nitrites Content at Remote East End of Distribution System

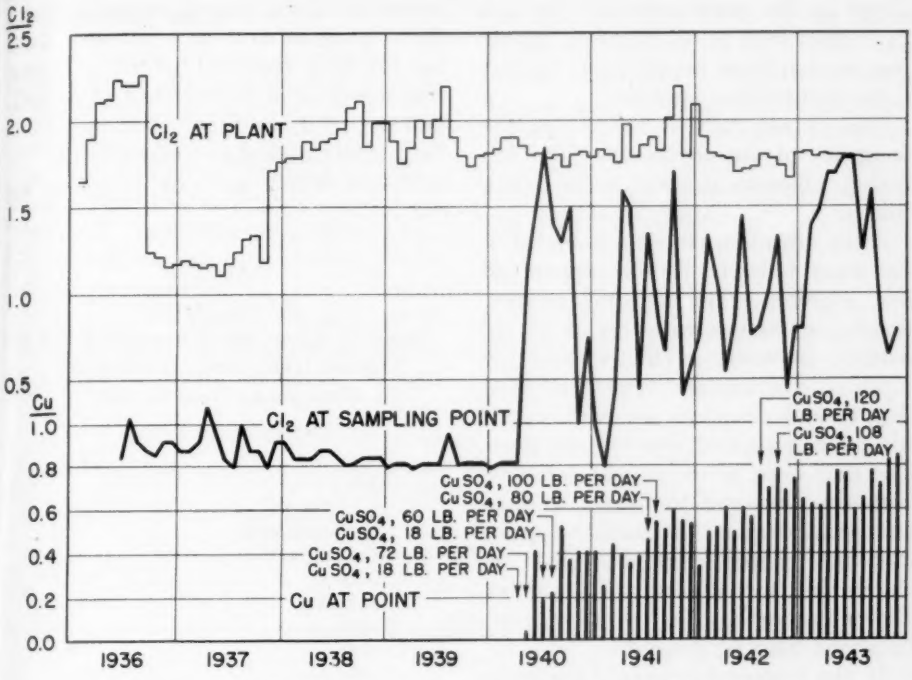

FIG. 4. Chlorine and Copper Content in Distribution System

and copper data are shown. The most pertinent of these in relation to the bad water complaints seems to be nitrites.

Figure 3 is presented as exemplifying typical results of nitrite tests before and after the copper treatment was started.

The horizontal line represents the average of all tests made at this sampling point for the years 1936, 1937, 1938 and 1939. Particular attention is called to the fact that during these years a maximum of 0.60 ppm. had been found.

The vertical lines represent the average of all nitrite tests made in each month during the years indicated. It will be noted that each year the tendency is toward decreased nitrites, with nitrites being indicated for three months only in 1943. Nitrite tests made at all other sampling points show this same trend.

Figure 4 illustrates the behavior of chlorine residual tests before and after the copper treatment was started.

The turreted line represents the average of chlorine residual tests at the plant effluent; the irregular line, the average of chlorine residual tests at the sampling point. The vertical lines represent the average of the copper tests at the sampling point.

Although the chlorine residual became erratic after the copper treatment was started, its trend is toward higher values. Most of the other sampling points show a like behavior, while three sampling points still show no chlorine residual.

The copper at this point is on the average about the same as that main-

tained in the plant effluent. In fact the copper tests at all sampling points disclose that there is practically no loss in the distribution system.

One is naturally interested in the chemistry of this treatment. The following suggestions seem to be possibilities.

After filtration, chlorine is added to the water followed by the copper sulfate solution. The chlorine unquestionably combines with a part of the natural ammonia in the water, thus forming chloramine. There is more than enough ammonia present to satisfy the chlorine applied, and it seems probable that some of the copper combines with the ammonia to form a copper-ammonia complex. It further appears that the copper combines with the chloramine, forming cupric-chloramine. Either one or both of the above combinations may be present.

If the copper-ammonia complex is present, the ammonia in this form may be more stable and thus is prevented from conversion to nitrites by bacteria. The same situation may govern in the case of cupric-chloramine.

Summary

Reviewing the data the following points seem significant:

1. Complaints of poor water are decreasing to a fairly satisfactory level and are coincident with the decrease in nitrites.

2. Chlorine residuals are progressing throughout the distribution system but progress has been so limited to date that improved conditions cannot be credited to this action.

3. Nitrites are on the decrease and have reached zero at several sampling points.

This article should be considered a progress report on a continuing experiment in the use of copper sulfate for a purpose and in a manner that has not been recorded before, in hopes that it will be of interest and value and will act as a challenge to bring about further discussion and experiment. A complete water analysis is given in Table 1.

TABLE 1

Mineral Analysis

(Sample of water collected from well owned by Illinois Water Service, Urbana, Ill. Date collected: June 12, 1938)

Determinations Made

	ppm.
Iron	
(filtered)	0.0
(unfiltered)	2.8
Manganese	0.0
Silica	17.5
Turbidity	20.0
Color	0.0
Odor	0.0
Calcium	61.3
Magnesium	31.8
Ammonium	4.5
Sodium	30.8
Sulfate	0.0
Nitrate	1.3
Chloride	0.0
Alkalinity as $CaCO_3$	
Phenolphthalein	0.0
Methyl Orange	362.0
Residue	354.0
Total hardness	283.0
pH	7.15
Free CO_2 (by test)	20.0
(calculated)	44–54

Hypothetical Combinations

	ppm.	*gpg.*
Sodium Nitrate	1.7	0.10
Sodium Sulfate	0.0	0.00
Sodium Carbonate	70.0	4.08
Ammonium Carbonate	12.0	0.70
Magnesium Carbonate	110.0	6.41
Calcium Carbonate	153.5	8.94
Silica	17.5	1.02
Total	364.7	21.25

Acknowledgments

The author wishes to express his appreciation of the co-operation of the Sanitary Engineer's Office of the Illinois Department of Public Health and the Director of the Champaign-Urbana Public Health District. It was the approval of these two departments that made this experiment possible. The author is indebted to J. G. Weart, chemist of the Illinois Department of Public Health, for his aid in setting up laboratory controls; to Dr. T. E. Larson and Dr. Max Suter of the Water Survey of the State of Illinois for their helpful and friendly suggestions in the the preparation of this paper; and especially to T. R. Dyer, Chief Plant Operator, for his diligent and intelligent management of every detail of control and tabulation of data.

Reference

1. Buswell, A. M. & Suter, Max. A Study of Floc Forming Organisms in Chlorinated Water Supplies. J. Bact., 39: 585 (1940).

Manual of Water Quality and Treatment

The first edition of the *Manual of Water Quality and Treatment* (American Water Works Association, 1940) is now completely exhausted. A new edition is in preparation under the direction of the officers of the Water Purification Division. A complete list of names of persons engaged on the project and the titles of the chapters on which they are working may be found on page 107 of the 1944 Membership Directory (Jour. A.W.W.A., 36:10, Part 2). It is hoped that the second edition will go to press during 1945.

Water Purification by Flotation

By Samuel H. Hopper

Asst. Prof. of San. Eng., School of Public Health, Univ. of North Carolina, Chapel Hill, N.C., and P.A. Sanitarian (R), U.S. Public Health Service, New York, N.Y.

A Contribution

THE flotation method for removing suspended and colloidal matter from an aqueous medium has been used with considerable success in the mining industry. The extension of this process to sewage flotation has been reported and, accordingly, it was hypothesized that the same principle should obtain for the removal of suspended and colloidal matter from raw surface waters.

A series of preliminary experiments was planned to determine whether the addition of a wetting agent to turbid water, followed by aeration and skimming off of the foam, would be effective in the reduction of turbidity, suspended solids and bacterial count. For this purpose 34 different raw water surface supplies, representative of those normally used in North Carolina, were obtained through co-operation with the Division of Sanitary Engineering of the State Board of Health at Raleigh, N.C. Using 1-l. samples, 20 ppm. of a wetting agent,* and 10-min. aeration, the following results were obtained. Their turbidities varied from less than one to as high as 620 ppm., while the suspended solids varied from zero to 380 ppm. One sample, having color but no turbidity, was rendered colorless by this process.

Some typical results are indicated in the five cases noted below:

Place	Turbidity *ppm.*		Suspended Solids *ppm.*	
	Raw	Treated	Raw	Treated
Raleigh	110	1	65	0
Spray	330	<1	322	6
Greensboro	620	20	380	12
Hickory	360	15	225	12
High Point	98	1	50	0

The average reduction in turbidity was approximately 70 per cent; the average reduction in suspended solids was approximately 79 per cent; and the average reduction in bacterial plate count was approximately 90 per cent.

On the basis of these preliminary results, it is suggested that the removal of suspended and colloidal matter from raw surface waters by the flotation method merits further attention. Extensive biochemical and engineering research may show that this process is practical for the preparation of water for filtration, that it would require less time than that taken by existing conventional methods, and that less equipment of different design would be involved.

* The wetting agent used was Roccal, made available by courtesy of the Winthrop Chemical Co.

Report of the Committee on Water Works Practice

Submitted to the A.W.W.A. Board of Directors, Jan. 10, 1945

THERE is submitted herewith the record of activities of committees organized by the American Water Works Association which are under the jurisdiction of the Committee on Water Works Practice.

This report also includes records of activities of joint committees of the A.W.W.A. and other associations, as well as committees of other organizations to which the A.W.W.A. has appointed representatives.

Water Works Practice Committees

1. *Deep Wells and Deep Well Pumps.* This committee is making adequate progress. The preliminary draft of the committee's report was discussed during the Milwaukee Conference. Since that time the co-chairmen of the committee, J. A. Carr and J. C. Harding, have carried on an extensive review of the earlier documents. It is expected that the final draft of the committee's report will be available for circulation among the members of the Committee on Water Works Practice and the members of the Board of Directors during the month of February 1945. At the time that these specifications are circulated for approval as tentative standard documents authorization will also be requested for publication of the specifications in the JOURNAL. It is desirable to give this material publicity through the columns of the JOURNAL at the earliest possible date.

2. *Watershed Protection and Maintenance.* The Board of Directors during the Milwaukee Conference authorized the organization of the Committee on Watershed Protection and Maintenance. Samuel B. Morris, immediate past-President of the Association, agreed to accept the general chairmanship of this committee. His undertaking the general managership of the Department of Water & Power in the City of Los Angeles made it necessary for him to relinquish this duty. It has been possible to obtain the consent of Earnest Boyce, Professor of Municipal and Sanitary Engineering in the University of Michigan, to head this important committee. Professor Boyce will take the work of the committee actively in hand during the first quarter of 1945. In the meantime, three subcommittees have been set up and their chairmen selected. The Subcommittee on Forestation will have as its Chairman E. E. Minor of New Haven, Conn. The Subcommittee on Erosion Control will have as its Chairman John S. Longwell of Oakland, Calif. The Subcommittee on Public Use of Watershed Areas will have as its Chairman L. S. Finch of Indianapolis.

3. *Manual of Water Quality and Treatment.* The 1940 Edition of the *Manual of Water Quality and Treat-*

ment is out of print and no more copies remain available for sale. The Water Purification Division has set up a group of eleven committees under the general chairmanship of A. Clinton Decker, immediate past-chairman of the division. The duty of this group is to revise the various chapters in the first edition of the manual. The work is proceeding. The preliminary draft of one chapter has been received and others are promised in the immediate future. It is anticipated that the text will be available for the printer by mid-year and that the revised edition will be available before the end of 1945.

4. *History of Water Purification.* Practically all of the manuscript of *The Quest for Pure Water,* by M. N. Baker, is now in galley form. Progress of the text has been delayed by the inability of the office staff to give attention to the editorial details. It appears that it will be possible to complete the publication of this text before mid-year 1945.

5. *Safe Handling of Water Works Chemicals.* This committee has previously submitted reports covering all chemicals commonly used in water works plants, which the chairman believes to be sufficiently hazardous to justify a report. Since these reports were based upon factual and consequently stable data, the probability of revisions of these reports in the near future is comparatively remote. For this reason, the chairman recommends that the committee be dismissed. (Approved by the Board on Jan. 15, 1945.)

6. *Steel Plate Pipe.* The discussion concerning manuals of information related to the design and installation of steel water pipe has resulted in the circulation of a memorandum dated Nov. 24, 1944, which asked the Water Works Practice Committee and the Publication Committee to review the outline of Chapter IV of the "Manual for Design and Installation of Steel Water Pipelines," which appeared in the October 1943 issue of the JOURNAL. The committee members addressed were asked to suggest any additions to, deletions from, and amendments of the proposed text which they felt were important. The preliminary digest of the reports received as of Dec. 29, 1944, has been furnished the Chairman of the committee, W. W. Hurlbut. A similar review of the content of the manual was carried on by the Steel Water Pipe Manufacturers Technical Advisory Committee. It will thus be possible for the Chairman of the A.W.W.A. Committee on Steel Pipe to have complete counsel concerning the content of this important manual.

The related discussion concerning the publication of a compendium of papers on steel pipe published in the JOURNAL has been laid on the table. The consensus of opinion now appears to be that every available effort should be put into the completion of the "Manual for Design and Installation of Steel Water Pipelines."

The chairman of the committee has recorded no suggestions concerning amendments to the current Steel Pipe and Coating Specifications.

7. *Reinforced Concrete Pipe.* Ernest Whitlock, who has been acting as adviser on this subject, has been asked to set up a complete committee within the A.W.W.A. to develop Specifications for Prestressed Concrete Pipe and to consider suggested amendments to the "Tentative Emergency Specifications for Reinforced Concrete Pressure Pipe," which may be submitted by any person interested. The New England Water Works Association

has appointed a committee to co-operate with the A.W.W.A. group.

8. *Fire Hydrants.* Roger W. Esty, Chairman of the Fire Hydrant Committee, is carrying on a review of field experiences with current specifications and has anticipated that a preliminary outline of the changes which the committee proposes to make in the current specifications will be presented for consideration of the Committee on Water Works Practice during 1945. Charles H. Becker, who had been the manufacturers' adviser of the Fire Hydrant Committee, died early in November and his successor is Louis W. Camerota, also an associate of the R. D. Wood Co.

9. *Sluice Gates.* The Committee on Sluice Gates, of which William R. Conrad is Chairman, has under consideration clauses in the specifications to provide for shop tests of completed sluice gates. On account of the involvement of manufacturers of sluice gates in the war effort, it will not be possible to complete this subject until the war emergency is over.

10. *Laying Cast-Iron Pipe.* This committee now operates under the co-chairmenship of Joseph E. Schwada of Milwaukee and C. K. Calvert of Indianapolis. The committee has been completely reorganized, with Mr. Schwada acting as chairman of the section of the specifications relating to the engineering and mechanical aspects of laying cast-iron pipe and Mr. Calvert as chairman of the section relating to sterilization of newly-laid mains. H. Lloyd Nelson is Adviser to Mr. Schwada and A. E. Griffin is Adviser to Mr. Calvert. The committee has no definite report at the present time.

11. *Valves.* The Committee on Valves is operating under the chairmanship of Fred M. Randlett, with Hubert F. O'Brien of the A. P. Smith Mfg. Co. as Manufacturers' Adviser. The committee has been very diligent in carrying on a survey of the field experience with the current valve specifications and the data thus developed have been forwarded to the committee chairman. It is anticipated that a preliminary outline of the proposed changes in the current specifications will be presented for consideration of the Committee on Water Works Practice during the next few months.

12. *Location Records and Maintenance of Mains and Services.* W. V. Weir, Chairman of this committee, reports no activities current within the committee group. He notes that the report of the committee was published in the JOURNAL for February 1940, and that he has received no suggestions concerning review of the recommended practice. It is his opinion that unless the Committee on Water Works Practice or the Board of Directors wishes to have the committee review the current document or wishes to assign other work to the committee that the committee should be discharged. (Action was deferred subject to further study of the matter.)

13. *Pipeline Coefficients.* Since early 1936 a Committee on Pipeline Coefficients has been set up with Clinton L. Bogert as Chairman. The committee carried on considerable activity in 1937–1938, but since that time has lost its momentum. It appears regrettably advisable to terminate the activities of the committee as presently organized. In the meantime, the California Section has set up a sectional group to study pipeline coefficients in the West Coast area. This committee is ready to undertake active study in the field and its progress will be promoted by the termination of the or-

ganization of the Water Works Practice Subcommittee on Pipeline Coefficients.

14. *Distribution System Safety.* Chairman William E. Stanley has returned from military service and has indicated his willingness to review the present "Tentative Manual of Safe Water Distribution Practices" to the end that the document be thoroughly adjusted to current conditions and thus receive more attention by water works executives. This is highly desirable and Chairman Stanley will be given all possible co-operation.

15. *Cross-Connections.* M. Warren Cowles, Chairman of this committee, has submitted to his committee members a preliminary draft of a new report for the Association. It is anticipated that this report in preliminary form will be available for discussion during the current year.

16. *Fire Prevention and Protection.* Charles J. Alfke, Chairman of this committee, reports no activities current. It appears desirable to initiate an inquiry within the Committee on Water Works Practice to see whether or not it is desirable to maintain this committee on a fully organized basis.

17. *Meters.* S. F. Newkirk Jr., Chairman of this committee, advises that "Specifications for Current and Compound Meters" are now in final draft form and will shortly go to the committee for balloting. The first draft of the "Specifications for Fire Line Meters" will be sent to the committee for review also in January. Recent modifications of Limitation Order L-154 make it necessary to revise the current "War Emergency Specifications for Domestic Meters."

18. *Electrolysis and Electrical Interference.* The statement concerning the A.W.W.A. policy on Grounding of Electric Current on Water Service Pipe, which was adopted by the Board in its January 1944 meeting and published in the February JOURNAL, has received wide attention. The report of the New York University studies on the effect of "Grounding Electric Service Lines on Water Service Pipes" was published in the May 1944 JOURNAL. The committee is carrying on no special activity subsequent to the publication of the report.

19. *Service Line Materials.* This committee, under Walter A. Peirce, Chairman, has been enforcedly inactive during the war emergency. Now that service line materials are becoming somewhat more available, the report of the committee, which has been held in suspense, will be reviewed and published in the JOURNAL. This report, it should be remembered, is a compendium of specifications covering all types of water service materials.

20. *Threads for Underground Service Line Fittings.* The activities of this committee are suspended as a result of wartime conditions.

21. *Valve Boxes and Covers.* The chairman expects to file a report during 1945.

22. *Valuation and Depreciation.* This committee, organized in January 1944, prepared a statement of position of the A.W.W.A. which was published in the June 1944 JOURNAL. This, together with related material, was republished in a brochure entitled "Depreciation—Fact or Theory" and was sent to all members of the National Association of Railroad and Utilities Commissioners. The activities of the A.W.W.A. committee, taken in connection with the activities of similar committees of the American

Society of Civil Engineers, as well as the American Institute of Accountants, evidently had an effect upon the thinking of the members of the NARUC. During the November meeting of that body, in Omaha, the report of that association's Committee on Depreciation was presented for adoption. The report was "received" and ordered "distributed for information," but it was *not* adopted as an official document of the NARUC. The work done by the A.W.W.A. committee during the current year is of such importance that the committee should be continued. The committee should be authorized to establish liaison with the A.S.C.E. committee and the committee of the Institute of Accountants to the end that the position of these groups be intelligently correlated.

(The Board voted that the special Committee on Depreciation, which was appointed in 1944 to consider the NARUC report, be continued. The function of the committee hereafter will be to study and report on matters related to depreciation procedures as they affect public water supply properties.

The Board approved development of contacts of the A.W.W.A. Committee on Depreciation with like committees of the A.S.C.E., American Institute of Accountants, American Bar Association and other groups which have a similar relationship to the broad problems of depreciation.)

23. *Radio Channel Allocations for Water Works.* In mid-year 1944, information came to the chairman of the Committee on Water Works Practice that a Radio Technical Planning Board had been organized for the purpose of appraising the use of radio communication equipment as an adjunct to operation of utilities, railroads and other public agencies. W. V. Weir of the St. Louis County Water Co. was thereupon appointed as an Adviser to the Committee on Water Works Practice and charged with participation in the activities of the Radio Technical Planning Board. A review of the use of radio by the larger water utilities was carried on by Mr. Weir and a digest of his findings was published in the December 1944 JOURNAL. The Association has participated in the hearings before the Federal Communications Commission and will continue to participate in the activities of the Radio Technical Planning Board until a final decision upon the current matter has been rendered by the FCC. It is definitely fortunate that it was possible for the Association to participate in this activity since, in time to come, water works executives over the country will wish to make use of radio communication equipment. If participation in this activity had not gone on during the year 1944, no provision could have been anticipated for the public water supply field.

24. *Water Use in Air-Conditioning Equipment.* As of Dec. 4, 1944, a memorandum was sent to the Committee on Water Works Practice and the Directors of the Association which outlined a discussion held and a resolution adopted by the Virginia Section. Comments on this memorandum have been valuable. It is evident that the Committee on Water Works Practice should be authorized to establish a Committee on Water Use in Air-Conditioning Equipment. The possible magnitude of the air-conditioning demand for water during the normal peak load season for water service is so substantial that some form of encourage-

ment of water economizing equipment must be developed through the activities of the Association's committee and made available to all water works executives for their guidance.

25. *The Methods of Testing Zeolites.* The committee at the present time has no activities in hand. The Water Purification Division will be asked to recommend that the manual advance to "standard" status unless a substantial body of dissent is filed.

26. *Capacities of Water Treatment Plants.* This committee, under the chairmanship of Douglas Feben of Detroit, has been actively engaged in a review of the subject matter of the committee's assignment. It has been found that the assignment to the committee is a bit difficult to handle as a committee activity, since the field is progressing rapidly and no body of a widely accepted basic data exists.

27. *Filtering Materials.* The Committee on Specifications for Filtering Materials remains inactive.

28. *Biological and Chemical Problems of Water Distribution Systems.* This committee has been organized during 1944 under the chairmanship of Marsden C. Smith. The Association members who have accepted appointment to the committee are as follows: L. C. Billings, R. J. Brehm, C. K. Calvert, R. F. Goudey, N. J. Howard, T. E. Larson, W. J. Scott, W. M. Wallace and A. D. Weston. The work of the committee has been initiated under proper auspices and adequate results from the work of the committee can be anticipated. The scope of the committee's work is defined as follows:

> To collect data relative to the effect of chemical and biological phenomena on the quality of water in distribution systems and on the pipes and appurtenances comprising distribution systems.

29. *Joint Administration of Water and Sewerage Works.* This committee as such has not been active during the year, although several individual contributions to the subject were made in papers presented at the Milwaukee Conference, which were later published in the JOURNAL. This subject is one of increasing importance and the reactivation of the committee under Leonard N. Thompson's leadership is anticipated.

30. *Standard Methods for the Examination of Water and Sewage.* The entire stock of 17,289 printed copies of the 8th Edition of this text has been exhausted. Photo-offset reproductions (1,500) with heavy paper covers have been produced to bridge the gap until the 9th Edition is published.

George Symons is engaged in the final editing of the new text. The administrative staffs of both the American Public Health Association and the A.W.W.A. profoundly hope that the new edition will be ready by mid-year 1945.

It should be recorded here that complete accord in administrative policy related to *Standard Methods* exists between the A.P.H.A. and the A.W.W.A. The joint relationship is so satisfactory that it is a landmark in the affairs of this Association.

The Federation of Sewage Works Associations has expressed its desire to be accepted as co-sponsor for future editions of this text. It now appears that affirmative consideration of this proposal is practical. When the organization of the joint editorial committee for the 10th Edition of *Standard Methods* is set up, the Federation's proposal will be given full consideration.

A proposal has been made by one of the Washington agencies that the

new text be translated into the Portuguese language and published for use in Brazil. It appears that this request should be granted, with the provisions that (1) the text also be published in Spanish at the earliest opportunity for use in other South American countries; and (2) it be sold (not given away) at the bare cost of production.

31. *Boiler Feedwater Studies.* As previously recorded, this committee has suspended its activities for the duration of the war emergency. The Executive Committee did not hold a meeting during 1944.

32. *Co-ordinating Committee on Corrosion.* This committee had one general meeting at the time of the New York Conference of the American Society for Testing Materials in 1944. Careful consideration was given to the future policies and activities of the committee at the time of the meeting. It was decided that no change would be made in the program of activities of the co-ordinating committee or in its schedule of expenditures until a special committee appointed for the purpose had reviewed the financial background of the committee's work and the possible avenues of its future activities. The Association contributes $50 per year toward the expenses of this particular committee.

33. *Construction Contracts.* The Joint Committee on Construction Contracts remains inactive.

34. *American Research Committee on Grounding.* The A.W.W.A. continues to be represented on the American Research Committee on Grounding. The latest report of this committee was published in the February 1944 issue of the JOURNAL.

35. *Water Works Terms.* Clinton L. Bogert was retained by the committee to act as editor of the document "Glossary—Water and Sewage Control Engineering" which has been developed under the direction of Thorndike Saville, General Chairman. This work is proceeding quite satisfactorily.

It is anticipated that the text will be available for publication during the latter part of 1945. Requests have already been received for the translation of this document into the Spanish language. It would appear quite proper to examine the propriety of the development of both Spanish and Portuguese texts so that the South American engineers and governmental agencies will have a complete record of the North American engineering terms related to the general subject of water resources and water supply.

36. *Water Works Accounting Manual.* No activity relating to the revision of this text is in progress.

37. *Joint Committee on Water Hammer.* There was no recorded activity of this committee during 1944.

38. *Specifications for Field Welding of Steel Water Pipe Joints.* The final report of this committee is now in preparation and the document will be available for approval and publication early in 1945.

39. *Survival and Retirement Experience With Water Works Facilities.* It is proposed to publish the report of the committee's activities (including the summaries which have been made from the reports of the cities which have furnished completed data) as soon as the text can be made available by the Supervising Co-ordinator, E. H. Aldrich.

40. *Steel Standpipes and Elevated Tanks.* This committee reports no revision of material at this time. The direction previously received by the committee to prepare a more extended section of the text on the subject of

painting new elevated tanks is on the calendar of the chairman of the committee but the work has not yet been completed.

41. *Wrought-Iron and Wrought-Steel Pipe.* The U.S. Bureau of Standards Committee on Wrought-Iron and Wrought-Steel Pipe has engaged in no activity during the year 1944.

42. *Cast-Iron Pipe and Special Castings.* The ASA A21 Committee on Cast-Iron Pipe and Special Castings has in progress the development of "Specifications for Cast-Iron Pipe Other Than Pit-Cast" and "Specifications for Fittings Larger Than 12 Inches." "Specifications for Short Body Fittings" are nearing completion.

It was recorded by memorandum to the Board of Directors, dated Dec. 5, 1944, that it had not been possible to develop authority upon which the Editor of the Association's JOURNAL could publish the "Specifications for Tar-Dip Coating for Cast-Iron Pipe" in the JOURNAL. Whenever such consent becomes available, the document will be published for the information of Association members.

43. *Manhole Frames and Covers.* No activity is current in this committee.

44. *Standardization of Plumbing Equipment.* This committee is making very good progress. Several meetings of the editorial group have occurred during the year 1944. It is hoped that the proposed "American Standard Plumbing Code" will become available for approval by the sponsor organizations during the year 1945.

45. *Pipe Threads.* This committee is active at the present time, having under discussion the standardization of pipe threads on an international basis involving American, Canadian and British standards. The following excerpts from the report of the Association's representative on this activity are of interest:

> In November and December 1943, discussions took place between the British Screw Thread Mission and representatives of Canadian and American industry and governmental agencies, while the British Mission was visiting this country.
>
> It was then agreed an American-Canadian Mission should visit London in 1944 to continue the discussions. Such a mission visited London, under the auspices of the Combined Production Resources Board of Canada, United Kingdom and United States.
>
> The Mission discussed in London numerous subjects in reference to individual screw threads as well as the unification of the British and American screw thread systems. Members of the Mission reported to industry the results of the London conference through a meeting held in New York on November 16, 1944, and sponsored by the American Standards Association, the American Society of Mechanical Engineers and the Society of Automotive Engineers.

Reports submitted at the meeting showed that substantial progress had been made toward international standardization of screw threads, but that many items still remained for further discussion.

46. *Pipe Flanges and Fittings.* This committee is at present engaged in work on the proposed "American Standard for Cast-Iron Pipe Flanges and Flanged Fittings for Refrigerant Piping, Class 300 Lb." and a proposed "American Standard for Bronze-Screwed Fittings, 125 Lb." The "American Standard for Cast-Iron Pipe Flanges and Flanged Fittings, Class 250," was finally approved and published during 1944.

47. *Pressure Piping.* This committee has prepared changes and additions to the November 1942 Edition of the "American Standard Code for Pressure Piping." They include changing

reference from A.W.W.A. "Specifications for Pit-Cast Pipe" to "American Standards Specifications, ASA A21.2." Also, reference to "Cast-Iron Bell-and-Spigot Pipe" has been changed to include A.W.W.A. and American Gas Association specifications.

48. *Standardization of Dimensions and Materials of Wrought-Iron and Wrought-Steel Pipe and Tubing.* This committee has considered a number of revisions and withdrawals of standard specifications which have been submitted by the A.S.T.M. The revisions consist of changes in "Welded and Seamless Steel Pipe, A.S.T.M. A53-42," "Electric Resistance Welded Steel Pipe, A.S.T.M. A35-42," "Spiral Welded Steel or Iron Pipe, A.S.T.M. A211," and other pipe specifications for high-temperature services. "Specifications for Forge Welded Steel Pipe, A.S.T.M. A136-34" and "Riveted Steel and Wrought-Iron Pipe, A.S.T.M. A138-34" have been recommended for withdrawal.

49. *National Electrical Code.* The National Electrical Code was originally developed in 1897 as a result of the efforts of various insurance, electrical and allied interests.

In recent years the National Fire Protection Association, acting under A.S.A. procedure, has sponsored the development of successive editions of the code. The last edition appeared in 1940 and a revision is now in progress. The A.W.W.A. participated in the development of Article 250 on Grounding. Charles F. Meyerherm is the A.W.W.A. representative and has attended several meetings of the subcommittee during the latter part of 1944, which meetings were called to consider revisions in the current document. Mr. Meyerherm, on Dec. 13, 1944, recorded his objections on behalf of the A.W.W.A. to certain sections in the proposed revisions. The attitude of Mr. Meyerherm is consistent with the position on grounding which was expressed by Board resolution in 1944.

In meetings of the committee appointed to revise "Electrical Code Article 250 on Grounding," exception has been taken to certain interpretations of the 1940 Article 2612-a on "Grounding to Water Pipes." Article 2612-a of the 1940 Code reads as follows:

> *2612-a. Grounding Conductor to Electrode. To Water Pipes.* System or common grounding conductors shall be attached to a water piping system on the street side of the water meter or on a cold water pipe of adequate current-carrying capacity as near as practicable to the water service entrance to the building. Where practicable, the point of attachment shall be accessible. If the point of attachment is not on the street side of the water meter, the water piping system shall be made electrically continuous by bonding together all parts between the attachment and the pipe entrance which are liable to become disconnected, as at meters and service unions. Equipment may be grounded to a cold water pipe near the equipment.

The grounding practices of some electric operating utilities are not altogether reasonable and they are in some degree led into erroneous practices by the phraseology of a "Supplement to the 1940 Code," issued Apr. 1, 1943. This supplement is in the form of a series of questions and answers. The series relating to Article 250 follows:

> Section 2523. Grounding Connection for Alternating Current. Interpretation No. 212. Issued May 26, 1941.
>
> *Question 1:* Does 2612-a require that the connection to a water pipe electrode for a common grounding conductor be located on the street side of the water meter?
>
> *Finding:* No.

Question 2: Does 2612-a require bonding jumpers around threaded couplings in water piping that is used as a grounding electrode?

Finding: No. Bonding jumpers are required only around meters and service unions which are in the water pipeline between the point where the grounding conductor is attached and the entrance of the pipe to the building.

Question 4: If a water pipe system used as a grounding electrode consists of copper tubing, the joints of which involve either solder or squeeze connections, does 2612-a require that bonding jumpers be employed around such joints?

Finding: No. Bonding jumpers are required only around meters and service unions which are in the water pipeline between the point where the grounding conductor is attached and the entrance of the pipe to the building.

Question 5: In applying 2612-a, is the cold water piping of the premises located on the house side of the water meter to be considered or used as the grounding electrode or as a part of the system or common grounding conductor?

Finding: It should be considered and used as the grounding electrode. Only the portion of the cold water pipe between the point of attachment of the grounding conductor and the point of water service entrance to the building is involved.

It will be recognized that the answers to the questions are not consistent with article 2612-a which they purport to interpret. These interpretations have in the case of at least one electric utility led to the strikingly non-co-operative position of requiring or attempting to require that the water utility serving the same area remove no meter from a line (where grounding connections exist on the house side of the meter) without arranging for an electric service man to be present and bond the line while the meter is being replaced. Since permanent bonding jumpers are clearly required by the plain English terms of article 2512-a, it is inconceivable that any electric utility should take the position indicated. The matter is hereby officially brought to the attention of the water works field.

50. *Zinc Coating of Iron and Steel.* The A.S.T.M. has suggested that the committee on this subject (under A.S.A. procedure) be dissolved and that the activities related to the subject matter be relinquished to the A.S.T.M. The Association is represented on this committee by Paul Weir and D. A. Russell. Mr. Weir believes that the committee should be continued and Mr. Russell believes that it should be disbanded. The Secretary of the Association has advised R. E. Hess, Assistant Secretary of the A.S.T.M., that the A.W.W.A. would like to defer decision on this subject.

51. *Letter Symbols.* Professor W. L. Malcolm, the Association's representative on this committee, advises that the committee has no project under consideration. The activity of such a committee is important to the engineering field and it is to be hoped that the committee can be reactivated by the A.S.A.

52. *Sieves for Testing Purposes.* This committee has no work in progress.

53. *Graphical Symbols.* During the year a preliminary draft of "Standards for Graphical Symbols for Telephone, Telegraph and Radio Use" was submitted to the committee members for approval. The co-ordinating report on "Electrical Graphical Symbols" was completed during the year, as well as a report on "Graphical Symbols for Electronic Devices."

54. *N.F.P.A. Committees.*

a. *Electrical Code Committee* activities are covered under Par. 49.

b. *Forests.* This committee is inactive and has no projects in hand.

c. *Hydrants, Valves and Pipe Fittings.* No project has reached completion during the year.

d. *Public Water Supplies for Fire Protection.* This committee is inactive.

e. *Elevated Tanks.* This committee is inactive.

55. *Inspection of Welded Structures.* This committee is active. It has under consideration minor modifications of the specifications document.

56. The Association was represented in a preliminary meeting called by the American Welding Society to consider a document on "Qualification of Welding Operators." It was the recommendation of Russell E. Barnard and Reeves Newsom, who attended the meeting, that the A.W.W.A. did not have enough interest in the subject matter to justify its participation in the activities of the committee. The A.W.W.A. will therefore not be directly represented on the committee. It will, however, through the activities of the Committee on Steel Pipe, be thoroughly advised concerning the results of organization of the Committee on Qualification of Welding Operators.

Respectfully submitted,

MALCOLM PIRNIE
Chairman

Report of the Publication Committee

Submitted to the A.W.W.A. Board of Directors, Jan. 10, 1945

1. The Journal

a. Text Contents: During 1944, the JOURNAL contained 1,434 pages of papers and abstracts. Included were these reports:

(1) Report of the Committee on Water Works Practice

(2) Emergency Minimum Sanitation Standards

(3) American Research Committee on Grounding—Interim Report of Investigations

(4) United States Public Health Service Recommended Sanitation Manual for Public Ground Water Supplies

(5) Report of a Research Project on the Effects of Electric Grounding on Water Pipes

(6) Report of NARUC Depreciation Committee (1943)

(7) Special Report of A.W.W.A. Depreciation Committee

The report of the audit of Association funds for the year ending Dec. 31, 1943, was published in the March 1944 JOURNAL. The December JOURNAL included: the report of the 1944 Conference; listing of Papers Scheduled at Section Meetings; and the Table of Contents and Indexes for the year.

In addition to the items cited above, a 160-page supplement to the October JOURNAL carried the biennial Membership Directory, and 152 articles were published in the JOURNAL. Of these, 129 articles were Conference or Section Meeting papers or contributions emanating from the field; and 23 articles were releases from WPB, Selective Service, etc.

b. Abstracts: A total of 121 pages of abstracts was published in 1944.

c. Advertising: Actual space total of 1944 advertisements was 570⅜ pages, compared with 539⅛ in 1943 and 468 in 1942. The amount of space for 1945 contracted for by Dec. 28, 1944, was 489⅝ pages. Since the total volume of advertising is never contracted for by this date, anticipated renewal of contracts terminating during 1945 warrants the expectation of at least as much space sales as last year.

d. Total Pages: The total of the above cited, including the News of the Field, official Association information at the front of the JOURNAL and the Membership Directory, was 2,436 pages. In 1943, the total was 2,552 pages.

e. Printing: Beginning in February 1944, the Association has paid for composition, press work and mailing operations at the rate of 10 per cent above the 1943 schedule.

In January 1944, the printing order was for 6,275 copies of the JOURNAL; in December 1944, for 6,500 copies. In 1943, the monthly publication rate increased from 5,373 in January to 5,900 in December.

The total cost of JOURNAL production in 1943 was $24,177.09. In 1944, the total was $23,814.34. Directory publication cost was $1,741.60.

f. Paper Stock: During 1944, the Association kept within its WPB allotment of 90 per cent of its 1942 consumption of paper, even though circulation increased 8.5 per cent and a 160-page supplement, the biennial Membership Directory, brought the number of issues to thirteen.

Because the Association's paper supplier advises that he is seriously behind in filling orders, he will not sell the Association more than 10,000 lb. of paper at a time, although the Association has bought by the carload heretofore. As a result, the paper will cost $9.10 per cwt. net, instead of $8.84 per cwt. net, as it did a year ago. In 1944, the Association sustained a 25.3-per cent rise in paper costs, when the price jumped from $7.20 per cwt. less 2 per cent, to $8.84 per cwt. net. The rise for 1945 will be an additional 3.28 per cent, an aggregate increase of 28.58 per cent.

The Association has on order 40,000 lb., to be delivered in four 10,000-lb. lots. The first lot is promised for delivery in the middle of January 1945. Paper consumption during the past three years is shown in the table below.

g. Censorship: During the first ten months of 1944, complete page proofs of each issue of the JOURNAL were submitted to the District Postal Censor in New York City for approval before printing. On Oct. 2, 1944, Col. N. V. Carlson, Chief Postal Censor, Washington, D.C., informed the Editor that such submission would no longer be necessary, and that any violations of the Code of Wartime Practices for the American Press, which might be discovered in JOURNALS marked for export, would be called to the attention of the Editor. No such violations have been reported. The JOURNAL continues to adhere to the Code to the best of the staff's ability. The JOURNAL is

Paper Consumption by Weight

	Lb.	*Lb.*
1942		
Text Paper, Journal and Reprints	57,199.01	
Cover Paper, Journal and Reprints	2,501.29	
TOTAL	59,700.30	
1944 Basis, 90% of 1942 Total Consumption		53,730.27
1943		
Text Paper, Journal and Reprints	47,524.50	
Cover Paper, Journal and Reprints	2,167.00	
TOTAL	49,691.50	
1944		
Text Paper, Journal	46,668.38	
Reprints	2,265.19	
Text Paper, Journal and Reprints	48,933.57	
Cover Paper, Journal	2,527.63	
Reprints	344.51	
Cover Paper, Journal and Reprints	2,872.14	
TOTAL		51,805.71
ACCRUED BALANCE, Jan. 1, 1945 (1944 use subtracted from 90% of 1942 total)		1,924.56

mailed only to readers in the United States and the Allied Nations, and since no doubtful material is put into production without previous explicit consent from the proper authorities, no problems are expected to arise.

2. 1944 Membership Directory

The 160-page biennial Membership Directory was published as a supplement to the October JOURNAL. A considerable saving in paper and manpower was effected by the use of the three-column page and the omission of advertising space. A total of 7,310 copies was printed, the additional ones being distributed to new members joining after October 1944.

3. Index to Journal

This text covers the material published from 1881 through 1939. One thousand copies were printed in 1940. Twenty-three copies were sold in 1944 and 333 copies remain in stock.

A new five-year cumulative index, covering the period from 1940 through 1944, will issue as a supplement to the March 1945 JOURNAL.

4. Standard Methods for the Examination of Water and Sewage

Reference to this activity is made in the report of the Water Works Practice Committee.

5. Manual of Water Works Accounting

Only 41 copies of this text were sold by the A.W.W.A. during 1944. This document should be the guide for the accounting staff of every water utility.

6. Specifications

Few large-lot sales of specifications were made during 1944. Many small-lot sales to federal agencies and contractors on war construction projects indicate the high standing of A.W.W.A. specification documents.

7. The Manual of Water Quality and Treatment

This was sold to the extent of 500 copies during 1944. Reference to this activity is made in the report of the Water Works Practice Committee.

Respectfully submitted,

LINN H. ENSLOW
Chairman

January 12, 1945

Report of the Audit of Association Funds for the Year Ending December 31, 1944

To the Members of the American Water Works Association:

The By-Laws require that the Secretary shall have made an annual audit of the books of the Association.

The records for 1944 have been examined by the staff of Louis D. Blum & Co. The complete record of that examination follows.

Reference may be made to past audits which appeared in the JOURNAL as follows: pp. 520–25, March 1938; pp. 570–74, March 1939; pp. 516–20, March 1940; pp. 774–78, April 1941; pp. 426–30, March 1942; pp. 338–42, March 1943; and pp. 359–63, March 1944.

There is also submitted a membership statement for 1944 and a comparative record for 1928–1944 inclusive.

Respectfully submitted,
HARRY E. JORDAN
Secretary

February 7, 1945

TO THE AMERICAN WATER WORKS ASSOCIATION:

We have examined the balance sheet of the American Water Works Association as of Dec. 31, 1944, and the statements of income and expenses and surplus for the year then ended, have reviewed the system of internal control and the accounting procedures of the Association and, without making a detailed audit of the transactions, have examined or tested accounting records of the Association and other supporting evidence by methods and to the extent we deemed appropriate. Our examination was made in accordance with generally accepted auditing standards applicable in the circumstances and included all procedures which we considered necessary.

In our opinion, the accompanying balance sheet and related statements of income and expenses and surplus present fairly the position of the American Water Works Association at Dec. 31, 1944, and the results of its operations for the year, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

(Signed)
LOUIS D. BLUM & Co.
Certified Public Accountants

EXHIBIT A—Balance Sheet, December 31, 1944

Assets

Cash in Banks and on Hand		$33,928.09*
Proceeds from sale of bonds, sold Dec. 28, 1944; check received Jan. 4, 1945		7,966.14
Accounts Receivable:		
Advertising	$1,951.10	
Reprints	9.95	
Other	99.57	2,060.62
Membership Dues		303.67
Accrued Interest on Bonds		420.30
Inventories:		
Paper stock	$909.85	
Type metal	434.67	
Manual of Water Quality and Treatment (13 copies)	8.06	
Cumulative Index (333 copies)	399.60	
Manual of Water Works Accounting (3 copies)	4.35	
Sundry publications	674.94	
Membership certificates	35.25	
Fuller Memorial Award certificates	26.56	
Back issues—Journals—Vols. 1 to 35, inclusive (29,144 copies)	—†	
Back issues—Proceedings—1881 to 1926 inclusive (306 copies)	—†	2,493.28
Office Equipment (Less depreciation)		3,799.18
Investments at Cost, including excess of redemption value of United States Savings Bonds over issue price—(Quoted market value Dec. 31, 1944, $78,550.00) Per Schedule 1		79,011.36
1945 Convention Expense		378.40
Total Assets		$130,361.04

Liabilities and Surplus

Accounts Payable	$547.45
Membership Dues—Advance Payments	16,469.15
Unearned Subscriptions to Journal	2,025.67
Reserve for Award Fund (McCord)	4.56
Reserve for Expenses of Carbon Research Committee	48.46
Surplus, Per Exhibit "C"	111,265.75*
Total Liabilities and Surplus	$130,361.04

* Canadian funds in the Bank of Montreal as at Dec. 31, 1944, amounted to $2,888.02 which, if converted into U.S. currency at that date, would have resulted in a loss of approximately $294.22. Had this loss been recorded, the cash in banks and the surplus would have been decreased accordingly.

† Back issues of Journals and Proceedings are inventoried but no money values are assigned to them for balance sheet purposes, inasmuch as the entire costs were charged off during the year of publication.

EXHIBIT A, SCHEDULE 1—INVESTMENTS—DECEMBER 31, 1944

Description	Interest Rate %	Principal Amount	Cost	Quoted Market Value 12/31/1944
City of Los Angeles	3½	$2,000.00	$2,241.11	$2,450.00
Province of British Columbia	4½	1,000.00	1,000.00	1,077.50
Province of Ontario	4½	2,000.00	1,690.00	2,070.00
Province of Ontario	4	1,000.00	732.50	1,140.00
Canadian Victory Bonds	3	6,000.00	5,647.75	5,400.00
Canadian Victory Bonds	3	2,000.00	2,000.00	1,782.50
Canadian Victory Bonds	1¾	2,000.00	2,000.00	1,795.00
United States Certificate of Indebtedness—Series B	⅞	3,000.00	3,000.00	3,000.00
United States Savings Bonds—Series C	2.9*	7,000.00	5,250.00	6,300.00†
United States Savings Bonds—Series C	2.9*	10,000.00	7,500.00	8,600.00†
United States Savings Bonds—Series D	2.9*	10,000.00	7,500.00	8,500.00†
United States Savings Bonds—Series D	2.9*	10,000.00	7,500.00	8,300.00†
United States Savings Bonds—Series G	2½	10,000.00	10,000.00	9,510.00†
United States Savings Bonds—Series G	2½	2,000.00	2,000.00	1,924.00†
United States Savings Bonds—Series G	2½	10,000.00	10,000.00	9,880.00‡
United States Savings Bonds—Series G	2½	2,000.00	2,000.00	1,976.00‡
United States Savings Bond—Series G	2½	5,000.00	5,000.00	4,845.00†
Excess of redemption value of United States Savings Bonds, Series C and D, over issue price			3,950.00	
			$79,011.36	$78,550.00

* Yield if held to maturity. † Current redemption value. ‡ Redeemable at the amounts shown on May 1, 1945.

EXHIBIT B—STATEMENT OF INCOME AND EXPENSES FOR YEAR ENDED DECEMBER 31, 1944

Operating Income:		
Annual dues	$53,742.21	
Advertising	35,370.64	
Subscriptions to Journal	3,371.38	
Convention registration fees	5,724.92	
Convention—other events	296.95	
Water and Sewage Works Mfrs. Association	7,500.00	
Interest on investments	2,354.67*	
John M. Goodell Prize	75.00	
Miscellaneous interest income	10.44	
Total Operating Income		$108,446.21
Publication Income:		
Manual of Water Quality and Treatment	$1,289.38	
Manual of Water Works Accounting	141.60	
Reprints	2,251.88	
Cumulative Index	38.25	
Membership certificates	48.90	
Proceedings and Journals	1,574.66	
One-half of profits from sales of *Standard Methods of Water Analysis*	631.44	
Specifications:		
Miscellaneous	123.90	
Meters	24.00	
Cast-iron pipe	299.38	
Steel pipe	187.00	
Elevated steel tanks	43.75	
Repainting tanks	42.95	
Gate valves	8.70	
Fire hydrants	8.70	
Sluice gates	14.05	
Water conservation	861.04	
Total Publication Income		7,589.58
Total Income (carried forward)		$116,035.79

* This account includes:

Profit on sales of International Telephone and Telegraph Company bonds	72.69
Loss on sale of Southern Pacific Railroad Co. bonds	15.10
Increment in redemption value on U.S. Savings Bonds for the year 1944	810.00

Total Income (brought forward)			$116,035.79
Operating Expenses:			
Directors' and Executive Committee Meetings:			
Travel expense	$2,687.82		
Stenographic expense	362.22	$3,050.04	
Administrative Expenses:			
Rent	4,100.00		
Office supplies and services	4,511.42		
Membership promotion	396.99		
General travel expense	109.44		
Legal and auditing expense	637.00	9,754.85	
Administrative Salaries		34,729.45	
Committee Expense		712.20	
Division and Section Expense:			
Division expense	$ 7.98		
Section—membership allotment	5,150.62		
Section—official travel	2,150.85		
Section—general expense	265.88	7,575.33	
Journal:			
Printing	16,597.96		
Production	3,013.90		
Paper	4,258.91		
Abstractors	277.36		
Membership List—1944	1,741.60	25,889.73	
Convention:			
General	2,175.54		
Entertainment	3,843.90		
Management committee	130.72	6,150.16	
Membership dues in other associations		575.00	
John M. Goodell Prize		75.00	
Fuller Memorial Award		7.95	
Depreciation of office equipment		615.71	
Miscellaneous expense		296.54	
Total Operating Expenses		$89,431.96	
Cost of Publications Sold or in Preparation:			
Manual of Water Quality and Treatment	$ 348.52		
Manual of Water Works Accounting	63.93		
Reprints	1,583.70		
Cumulative Index	27.60		
History of Water Purification	120.95		
Membership certificates, including lettering and mailing	55.01		
Journals and Proceedings	3.50		
Specifications:			
Miscellaneous	18.10		
Meters	20.63		
Cast-iron pipe	237.78		
Steel pipe	130.89		
Elevated steel tanks	22.74		
Repainting tanks	30.80		
Gate valves	2.30		
Fire hydrants	4.35		
Sluice gates	1.25		
Water conservation	438.65		
Total Cost of Publications Sold		$3,110.70	
Development Expense—Research:			
Depreciation—water works structures	$ 266.32		
Wartime activities	1,089.55		
Glossary—Water and sewage control engineering	600.00		
Water and sewage development	4,597.85		
Total Development Expenses		6,553.72	
Total Expenses			$99,096.38
Net Income for the Year (Transferred to Exhibit "C")			$16,939.41

EXHIBIT C—SURPLUS ACCOUNT FOR THE YEAR ENDED DECEMBER 31, 1944

Balance, Jan. 1, 1944	$94,326.34
Add: Net income for the year, per Exhibit "B"	16,939.41
Balance, Dec. 31, 1944, per Exhibit "A"	$111,265.75

Membership Statement—Year of 1944

	Active	Corporate	Associate	Honorary	Junior	Affiliate	Total
Total Members, Jan. 1, 1944	4163	442	238	29	19	79	4970
Changes in Membership Grades	−1	—	1	3	−2	−1	——
	4162	442	239	32	17	78	4970
Gains:							
New Members During 1944	636	69	21	—	4	4	734
Reinstated During 1944	76	10	4	—	—	2	92
	4874	521	264	32	21	84	5796
Losses:							
Resignations and Deaths	123	4	6	3	1	3	140
Dropped for Non-payment	154	7	3	—	1	6	171
Total Members, Dec. 31, 1944	4597	510	255	29	19	75	5485
Total Members, Jan. 1, 1944	4163	442	238	29	19	79	4970
Gain in Year of 1944	434	68	17	—	—	−4	515

Comparative Statement—Gains and Losses—Seventeen-Year Period

Year	New	Reinstated	Resignations and Deaths	Suspended for Non-payment of Dues	Gain or Loss	Total Members at End of Year
1928	203	36	99	126	+14	2456
1929	314	25	118	130	+91	2547
1930	501	39	122	134	+285	2831
1931	203	22	123	216	−114	2717
1932	117	22	169	297	−327	2390
1933	168	56	159	234	−169	2221
1934	271	66	86	122	+129	2350
1935	565	42	85	190	+332	2682
1936	311	53	104	218	+42	2724
1937	515	86	122	139	+340	3064
1938	520	59	144	140	+295	3359
1939	578	64	112	179	+351	3710
1940	514	58	113	212	+247	3957
1941	480	92	116	236	+220	4177
1942	570	59	132	233	+264	4441
1943	769	88	130	198	+529	4970
1944	734	92	140	171	+515	5485

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **34:** 412 (Mar. '42) indicates volume 34, page 412, issue dated March 1942. If the publication is paged by the issue, **34:** 3: 56 (Mar. '42) indicates volume 34, number 3, page 56, issue dated March 1942. Initials following an abstract indicate reproduction, by permission, from periodicals, as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

WARTIME WATER WORKS PROBLEMS

The Development of Emergency Sources of Water Supply. ANON. J. Inst. Civ. Engrs. (Br.) **19:** 275 (Feb. '43). Provision of emergency water supply for domestic purposes in event of failure of normal piped supplies subject that has received consideration by all water authorities supplying 20,000 consumers or more. Object of paper is to set forth scheme approved by Ministry of Health and undertaken by city in '41. 44 indus. drilled wells, with depth of from 200 to 1000′ located within city. 15 selected as water points. Preference given to those using steam power generated at site. Each water point provided with facilities for filling mobile tanks. Delivery capacs. vary from 3000 to 25,000 gal. (Imp.) per hr. Works carried out do not interfere with normal operation of indus. establishments. 7 gasoline-driven mobile power units constructed with view to insuring operation of those installations using elec. power. One of greatest problems to be met in most cases in connection with emergency water supply distr. to consumers. Following quants. agreed upon as min. supplies per 24 hr: hospitals, 5 gal. (Imp.) per bed and per head of staff; rest centers, 1½ gal. (Imp.) per head where cooking facilities available and 1 gal. (Imp.) per head where no cooking facilities present. General public will be supplied by 2 methods: (1) static tank located within ¾-mi. radii of water points with 1½ gpd. (Imp.) per head; (2) mobile tanks distributing 1 gpd. (Imp.) to consumers outside ¾-mi. radii referred to above. Static installations comprise 2 steel tanks, one placed about 8′ above ground level to allow free passage for public to draw supplies from 16¾″ taps fixed at bucket height. Upper tank provided contact period to effect sterilization. With view to organizing work of distr. by mobile tanks, area divided to facilitate refilling at allotted water points, and also for gasoline servicing and parking. Various anals. carried out on supplies from respective installations. Deemed advisable that simple system of sterilization should be put into operation. Chlorination by use of "Staboclor" adopted. Selected laborers trained in its application. Tests indicate satisfactory results. To remove taste from chlorophenol products due to action of chlorine on bituminous paint tanks filled with water contg. 80 ppm. of chlorine and allowed to stand for 24 hr. before being completely flushed out.—*H. E. Babbitt.*

Emergency Water Supply From Local Sources. ANON. Wtr. & Wtr. Eng. (Br.) **47:** 439 (Oct. '44). From Inst. of Water Engrs. Recognized min. allowance of water for drinking and cooking is 1 gpd. (Imp.) per head. In addn., certain priority consumers, such as hospitals, etc., would require supplies. With these considerations in mind scheme for densely populated and nationally important area evolved. List of all known local sources drawn up. Consultation with owners and testing at source revealed information on yield, qual., pumping plant, storage, etc. Samples of water collected for anal. and for testing chlorine demand. Results of survey showed 20 sources suitable for use which would yield 3 gpd. (Imp.) per head. Sources divided into 3 categories: (a) yielding good qual. water exceeding 1000 gal. (Imp.) per hr., (b) yielding at less rate than 1000 gal. (Imp.) per hr., and (c) yielding water of abnormal characteristics requiring special treatment. Obvious that saving in manpower could be effected by full use of larger sources. Sterilization by chlorine simplest practicable treatment in emergency either with or without de-chlorination. Bleaching powder chosen as agent because of its availability in sufficient quant. in emergency.

Standard dosing soln. gave nominal 0.83% chlorine soln. 1 pt. added to 1000 gal. (Imp.) represents dose of 1 ppm. Table prepd. for each source showing: (1) min. dose required to leave residual of 1 ppm. in 30 min., (2) rate of discharge from pump, (3) discharge of orifice installed, (4) strength of dosing soln., and (5) nominal dose. Nominal dose exceeded min. requirements in all cases by at least 25%. Existing pumps used wherever available. Those depending on town's electricity provided with independent source of power. Existing storage tanks incorporated in the scheme wherever possible. Outlet pipes for storage tanks connected to corporation's trunk mains or to convenient point for filling mobile tanks. Provision made for public to draw water from ranges of faucets on sites. Distr. points so sited that majority of consumers within 330 yd. of nearest point. As much of area as possible served by trunk mains from which supplies would be given at conveniently situated fire hydrants. System of mains used consisted of inner and outer ring with connections and with loop mains branching off outer ring to serve outlying areas. Mobile tanks provided for distr. direct to public. Certain employees trained as water wardens. Although scheme has suffered damage at hands of enemy, it has not been subjected to type of ordeal for which it was intended.—*H. E. Babbitt.*

Errors in the Use of Field Testing Outfits in the Disinfection of Water. T. R. BHASKARAN, C. V. SABNIS, C. CHANDRA SEKAR & K. SUBRAHMANYAN of All-India Inst. of Hygiene and Public Health, Calcutta. Wtr. & Wtr. Eng. **47:** 499 (Nov. '44). Existing procedures of disinfecting water in field neither scientific nor satisfactory. Potassium permanganate and bleaching powder used. No quick method of testing efficacy of disinfection by potassium permanganate in field. Other disadvantages in use of permanganate: high cost, slow action, increase in color, fishy taste and concn. of residual Mn have long been recognized. Horrock's outfit simple and well suited for field work to det. amt. of bleaching powder to be added to water for proper disinfection. Outfit widely used in British army. Starch-iodide indicator, used in Horrock's test, not so delicate as o-t. reagent. Errors in test due to variation of: (1) wt. of powd. measured by spoon, (2) capac. of different spoons, (3) vol. of water filling black cup (in which stock solns. made) to mark, (4) capac. of different black cups, (5) drops from same dropper, (6) drops from different droppers, (7) vol. of water when same white cup filled to brim, and (8) capac. of different white cups. Expts. carried out to compare sensitivity of cadmium-iodide starch indicator of Horrock's outfit and o-t. reagent prepared according to *Standard Methods*. Results show o-t. reagent 10 times more sensitive than cadmium-starch indicator. Simple field kit evolved along lines of Horrock's outfit, using o-t. in place of starch-iodide indicator. In new outfit spoon and white cup errors more or less same as in Horrock's, but dropper error has been reduced. Underdosing successfully prevented in both methods but overdosing will necessarily occur to varying extents. Outfit for disinfection of water in field should be compact, consist of simple equip., and be capable of easy manipulation by men with little tech. training. Horrock's outfit simple and compact, and, in spite of large exptl. errors, insures no underdosing.—*H. E. Babbitt.*

Water Hygiene in War. W. SCHMIDT-LANGE. Deut. Militararzt (Ger.) **5:** 324 ('40); W.P.R. **14:** 363 ('41). Hygiene of water supplies small but important part of province of hygiene experts in field. Sources of water found in occupied country must be examd. immediately and good supplies made known and protected from poln.; unsuitable sources of supply should be marked clearly or made unusable. In field 10 l. of water per day per head must under some circumstances suffice. Often necessary to use rain water. When large quants. of water not required supply can be obtained by pipe wells (Abyssinian wells). War conditions may cause damage to water works and distr. systems, and broken sewers may cause poln. of water supplies. Examn. of water in field must be restricted to most important points. Inspection of source must never be omitted. Usual methods of bacteriol. examn. too slow for use in field and author recommends detn. of total count on agar at 37°. Chem. and phys. anals. cannot be carried out under mobile conditions but must be resumed when more stable conditions attained. Rules given for chlorinating water in field. Filtration in addn. to chlorination beneficial.—*C.A.*

Maintenance and Operation of Public Utility Automotive Fleets. JEAN Y. RAY. Edison Elec. Inst. Bul. **12:** 168 (June '44). Rumored possibility of breakdown of auto

transportation in general not applicable to public util. fleets due to sound maint. programs. Doubtful that WPB will provide many trucks this year as armed services come first, and factories must work to capac. to meet their orders. ODT rehabilitation program will supply replacement motors, rear axles or other parts which will extend vehicle use for 3 or 4 more years. Under this new order operators of 25 or more vehicles entitled to get without priority rating or any restrictions, one motor, one transmission and one rear axle for each vehicle owned. Old motor may be removed and exchanged for rebuilt motor. Under program 137,000 motors, 8000 trans. and 3800 rear axles will be built. Ford, Chevrolet and General Motors expected to participate strongly, but mfrs. of larger motors will be reluctant to enter program unless orders placed early. Replacement parts situation improved some with exception of cylinder heads, crankshafts, and gears which are still in demand by army. Parts now made of improved materials and WPB has agreed to set aside for civilian production 5% of manpower hours used in mfr. of parts. Most of production of vehicles this year in medium- and heavy-duty class, with which army replacing lighter equip., so little, if any, will be available for public util. fleets. Army suggests use of their discarded lighter vehicles but this not advisable as they are expensive to operate and maint. and have been abused. Synthetic rubber tires will be available and in passenger car size will give good service if given good care; however, larger tires for trucks not as satisfactory. Overloading of synthetic truck tires very harmful; they do not dissipate heat and have ignited, causing fires and destroying both truck and cargo. Some fleet operators run trucks through trough of water 200 to 300′ long at end of run to cool tires. Low mileage from poor grade of gas now available necessitates request for larger allotment. First postwar trucks manufactured may not be best investment, so do not rush to purchase them.—*H. J. Chapton.*

Saving Metals to Hurry Victory. A. E. HOLDEN. The Driller **17:** 6: 7 (June '43). Many metal shortages creating delays and making replacement parts unobtainable, launched new service called metallizing, "metal spraying" process for rebuilding worn surfaces on crankshafts, pistons, transmission shafts and other wearing surfaces including well drilling and water system equip. Highly specialized service managed by competent automotive jobbers and machine shops with trained knowledge of metals and their successful application, available in almost any sizable city. All kinds of shafts, impellers, centrifugal, boiler feed and reciprocating pumps successfully metallized. Costs vary according to part, metal and subsequent machining, but price worth it when new parts unobtainable. Metallizing not a cure-all.—*Ralph E. Noble.*

Means for Conserving Labor and Materials, Including the Adoption of Substitute Noncritical Materials. G. E. MARTIN *et al.* Am. Ry. Engr. Assn. **45:** 441: 64 (Nov. '43). Salvaged and substitute material should be used wherever possible. Man-hours should be conserved by good transportation and communication service for repairmen. Work should be carefully planned and anticipated requirements ordered well in advance.—*R. C. Bardwell.*

Electric Pumping Will Save Critical Materials. C. R. KNOWLES. Ry. Eng. & Maint. **40:** 2: 131 (Feb. '44). Extension and interconnection of elec. power lines has increased availability and dependability of this source of power for railway water stations. Critical materials saved by less wt. of motor-driven centrifugal units and automatic control conserves labor. Coal and oil saved, as well as coal cars or oil tank cars in which serious shortage exists.—*R. C. Bardwell.*

The Use of Alumino Ferric in the Field for the Treatment of Water Containing Colloids. S. KNIGHT. J. Roy. Army Med. Corps (Br.) **82:** 2: 38 (Feb. '44). Water from natural sources frequently contains colloidal particles which pass through std. army metal filters even when these are aided by Kieselguhr, so that filtrates turbid and colored. Prelim. coagulation of these colloids by means of alumino ferric prior to filtration will provide clear water, but this method has hitherto been employed only where settlement in tanks possible. Methods here described for using alumino-ferric coagulation with both Mobile Water Purifier, Mk. II, and with unit app. Expts. with mobile purifier demonstrated that by adding between 1 and 2 gpg. of alumino ferric to water by means of Filtraider device, together with Kieselguhr, which is normally added in this way on suction side of pump, entirely satisfactory filtrate can be

obtained with waters which ordinarily yield turbid, colored filtrate.—*B.H.*

Water Service Men Are Finding Ways Around Problems. A. B. PIERCE. Ry. Eng. & Maint. **40:** 4: 356 (Apr. '44). Curtailment in availability of materials and equip. has resulted in railroads salvaging many old units. Heavy increase in traffic caused by movement of war supplies has required new water stations and enlargement of many old supplies. Pipeline efficiencies have been increased by cleaning and many new wells installed. Troop train movements have required new drinking water facilities. Curtailment by WPB in qual. of alum and amt. of chestnut extract used in water treatment has not affected railroad water supplies seriously as yet.—*R. C. Bardwell.*

Reflections on the Gages of the Portland Water District Showing Water Pressure During Blackouts. F. J. RENY. J. Me. Water Utils. Assn. **19:** 117 (Sept. '43). During 3 successive blackouts Dist. water use decreased approx. 5 mgd. in 20 min., accompanied by 2–3 lb. increased pressure. No explanation other than actual decreased consumption during blackout.—*Ralph E. Noble.*

DAM CONSTRUCTION AND MAINTENANCE

Earth Dams—Their Design and Causes of Some Failures. MILTON G. SPEEDIE. Surveyor (Br.) **103:** 99 (Mar. 3, '44). Essential requirements of earth dam: (1) Sufficient height and top width against overtopping and wave wash. (2) Materials suitable for purpose. (3) Dam and foundation must be sufficiently impermeable. (4) Veloc. of water percolating through bank and foundation must be low enough to insure that no fine soil particles removed. (5) Profile must be such that materials of embankment and foundation stable under most unfavorable combination of shear characteristics and pore pressure that may be encountered. Following design procedure suggested: (1) Make thorough survey of materials (a) in foundation and (b) in vicinity of site and available for new constr. (2) Select one or more trial cross-sections and zonings of materials. (3) Exam. trial designs for (a) seepage loss and safety against piping and (b) stability of embankment and foundation. (4) Det. final cross-section after consideration of characteristics of various alternatives considered and cost of each. (5) Carry out model tests to check seepage and stress conditions, and to assist in prepg. constr. program. Three basic types of earth dams are: Type A, composed entirely of one material except for surface protection against erosion; Type B has materials symmetrically zoned; Type C has materials non-symmetrically zoned. Foundation materials must be examd. in their natural condition. During constr. fill material will be excavated, transported, spread and compacted. Necessary to det. properties soil will exhibit after this treatment. Necessary top width remains matter for judgment. Amt. of freeboard usually detd. from wave height considerations. Deg. of impermeability depends on value of water stored and dimensions of embankment. Essential to design structure so that seepage gradient will be well below "flotation" value at points where seepage water will issue from soil mass. Earth dam stability largely governed by hydrostatic pressure of fluid—air and water—in voids of soil mass. These pressures may be produced by: (1) compaction equip. during constr.; (2) superimposed weight of soil mass during consolidation period and; (3) seepage flow through soil mass. Lack of adequate spillway caused greatest number of failures. Only few failures attributed to insufficient stability of embankment or its foundation. Failure of structures in recent years caused by weak foundations in large proportion of cases. Low height of dam does not warrant taking risks. History has shown that greatest number of failures occur in relatively low dams.—*H. E. Babbitt.*

San Roque Dam, Argentina. ANON. The Engr. (Br.) **177:** 509 (June 30, '44). San Roque Dam located on River Primero, near Cordoba in Argentina. River subject, particularly in late spring, to heavy floods, while at other times of year drought prevails. Dam is concrete gravity structure, slightly curved in plan and has height above river bed of about 50 m. Reservoir will have area of 1650 ha. and vol. of about 200 cu. hectometers at normal storage level. Catchment amts. to 1350 sq.km. Bell-mouthed spillway can discharge 230 cu.m. per sec. at top water level into reservoir.—*H. E. Babbitt.*

German Dams Attacked Successfully. JOSEPH D. LEWIN. Eng. News-Rec. **130:** 890

(June 17, '43). During night of May 16–17, 11 of 19 attacking planes succeeded in breaching Moehne and Eder Dams in Western Germany with 65 tons of explosives. Exact damage not known but photos reveal gap 250′ long and 42′ deep in crest of Moehne Dam and breach approx. 200′ long and of unknown depth in Eder Dam. Both dams curved gravity type structures located in Rothhaar Mts. in Ruhr Dist. and forming reservoirs among largest in Germany. Timing of attack with respect to hydrologic cycle perfect, as in avg. yr. reservoirs full by May 15. Photos show Moehne Reservoir to have been full. Details given of dams and ests. made of probable damage. Estd. that only 70% more mines used than theoretically necessary, indicating very exact bombing. Believed that greater part of stored water released and estd. that max. discharge from breached Moehne Dam about 172,500 cfs. and from Eder Dam about 125,000 cfs. If reports true that Ruhr Valley below Moehne flooded for 60 mi., avg. depth of water about 3′. Will be repercussions in shortage of water to more than 250 municipalities, several hydro plants and navigation canals. Several other dams in Germany mentioned as suitable targets for attack.—*R. E. Thompson.*

The Block Eary Dam, Isle of Man. T. N. C. BULMAN. Wtr. & Wtr. Eng. (Br.) **46**: 461 (Nov. '43). Purpose of dam to impound water for supply to north of Isle of Man. 3 methods of water supply reviewed: (1) gravitational, (2) from river and (3) underground. Consideration of available gathering grounds directed choice to valley site adopted. Site favored constr. of concrete or masonry dam, not more than about 50′ in height, forming reservoir of 11 bil.gal. (Imp.) capac. Hills of slate traversed by quartz. At north end of dam rock hard and compact with no obvious cracking. At southern end rock chunky in character with many cracks and visible bedding planes. Catchment area approx. 1040 acres with approx. avg. annual rainfall of 55″. Top water level of dam 606 O.D. (Ordinance Datum) and allowance made for max. flood of 600 cfs. Nature of site most suitable for mass concrete dam. Height from stream bed to spillway crest approx. 50′ and max. thickness 43′10″. Overall length 208′ 8″. Spillway length 30′. Little earth to be excavated, site mostly rock on surface. Foundations, particularly in way of tongue (cutoff) trench, after excavation drilled and grouted but usually found that holes took no water under pressure of 80 psi. and so took no grout. Concrete shot down chute from mixer and allowed to be rather wet with water-cement ratio of 0.7. It took 20 days for reservoir to fill. No wet patches appeared on downstream face. At southern end, where qual. of rock was suspect, one small leak appeared. Leakage already dropped to 1000 gal. (Imp.) per day.—*H. E. Babbitt.*

Pressure and Consolidation Measurements at a Western Earth-Fill Dam. ELLIS L. ARMSTRONG. Civ. Eng. **12**: 682 (Dec. '42). Dam typically zoned rolled earth-fill type, having center section of impervious sandy-clay material with supporting upstream and downstream sections of stable comparatively semi-pervious materials increasing in coarseness toward outer slopes. Max. height of 235′ above bedrock, length at crest of about 1300′ and contains little less than 3 million cu.yd. of earth and rock materials. Between small closely packed particles that make up embankment, are inter-connected pore spaces which permit flow of air and water through materials. As embankment consolidates and as reservoir fills and empties, air and water exerts pressures on surfaces of pore spaces. This "pore" pressure very materially affects stability of dam. Piezometer apparatus installed in dam to measure this pressure during constr. and during later operation of reservoir. From data obtained, extent of satn., percolation stream lines and stability of embankment can be detd. during both constr. and operation. Five settlement measuring systems installed in dam, making total of 123 crossarms. From time each pair of crossarms placed until 4 mo. after embankment completed, consolidation between crossarms showed approx. straight-line variation of from zero at top of embankment to about 3% with 150′ of fill load. Amount of slow long-time consolidation of embankment yet to be detd., as is settlement effect, if any, of satn. by water from reservoir. —*H. E. Babbitt.*